SPECIAL ISSUE: The Solar System

ORIGINS 37/38

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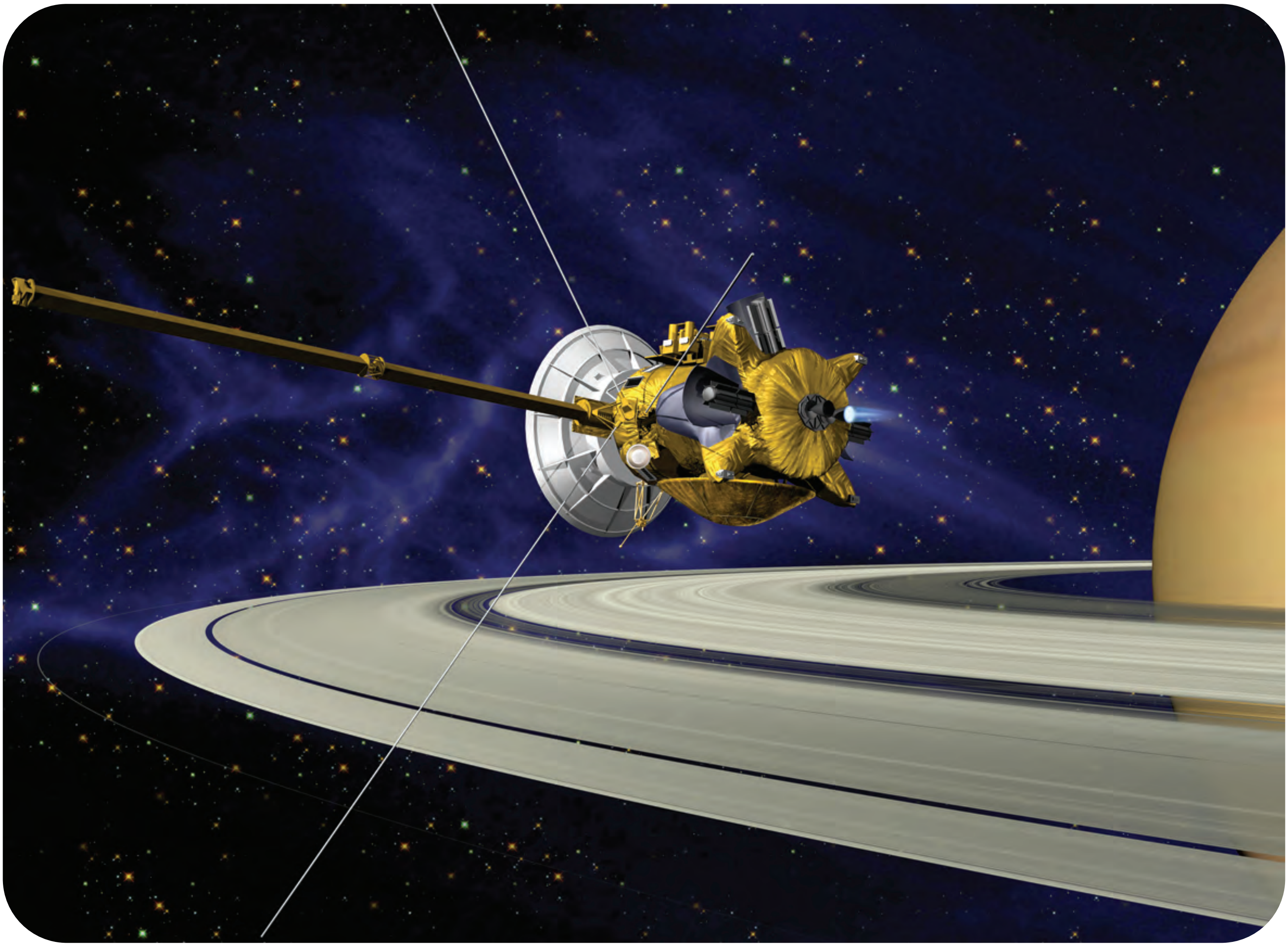


EDITORIAL

VOYAGE TO THE PLANETS

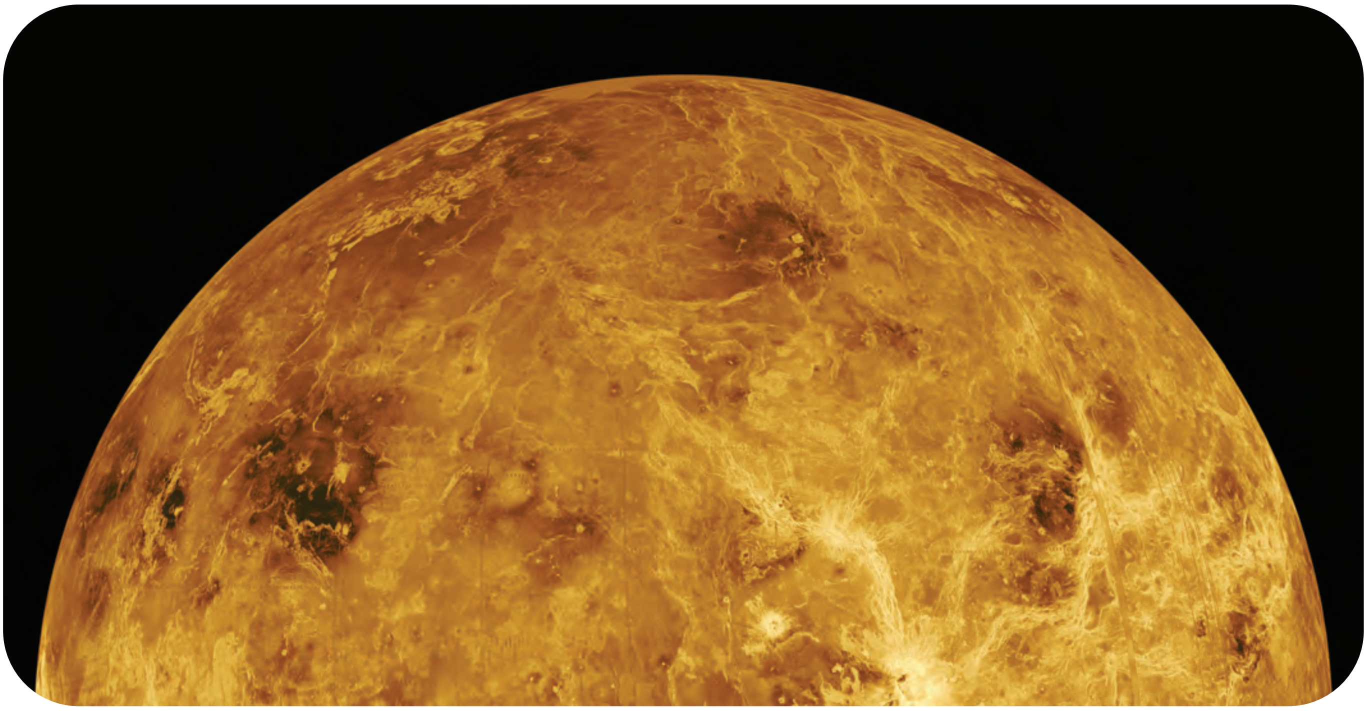
The Voyager 1 and Voyager 2 spacecraft were launched by NASA in 1977 on a mission to explore the outer solar system. For more than a decade they sent back stunning images of Jupiter, Saturn, Uranus, and Neptune – not to mention a host of moons and ring systems. The mission concluded when Voyager 2 swept past Neptune in 1989. By November 2003, Voyager 1 was approaching the boundary between our solar system and interstellar space – a region called the 'termination shock'. In this region, the solar wind abruptly decelerates where it meets the tenuous interstellar medium. Voyager 1 had reached the very edge of our solar system.

In this special issue of *Origins* we too will be going on a journey through our solar system. Our excursion will take us thousands of millions of kilometres – but compared with the vastness of the universe we will only be exploring our backyard! However, there are amazing things to see at every turn. From the barren cratered terrain of Mercury to the frozen wastes of Pluto, from the rocky inner planets to the gas giants of the outer solar system, we will take a look at the wonders revealed by modern space exploration. Along the way, we will be thinking about the origins of our solar system. Where did it come from? How did it form? What role – if any – have catastrophes played in shaping it? Did it originate by natural processes operating over billions of years – or by special creation not so long ago?

To guide us on our journey, we have assembled a team of respected authors. They will present us with an up-to-date survey of our nearest neighbours in space. Their aim will be to help us understand the latest scientific and biblical thinking about the planets and satellites of our solar system. We trust that your faith will be encouraged as you learn of the many ways in which the latest research and discoveries confirm the biblical record of origins. To accompany these fact-filled articles, we have sought out some of the most striking images returned by spacecraft such as the Voyagers, Galileo, and the Mars Global Surveyor. We feel sure that you will enjoy the visual treat! Above all, we hope that this issue of *Origins* will encourage you to praise and worship the Creator who spoke all these things into existence and who upholds them by his powerful word. "All things were made by him; and without him was not any thing made that was made" (John 1:3).

PAUL GARNER

Cover: An artists' conception of the spacecraft Cassini during the Saturn Orbit Insertion, just after the main engine has begun firing. This manoeuvre will allow Cassini to be captured by Saturn's gravity into a five-month orbit. Cassini's close proximity to the planet will offer a unique opportunity to observe Saturn and its rings at extremely high resolution. © NASA/JPL.



A global view of the planet Venus. © NASA/JPL

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In 1999, the final solar eclipse of the twentieth century took place. David and Sheena Tyler were on holiday in Devon to see it happen. Here they offer some thoughts on the experience – and outline a Christian response to this amazing phenomenon.

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These icy giants with deep atmospheres and extraordinary weather patterns are among the most mysterious objects in our solar system. Uranus even rolls around its orbit on its side! Paul Garner describes the unique characteristics of these peculiar worlds and shows that evolutionary theories have so far failed to account for them.

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The outer solar system is the realm of the comets – 'dirty snowballs' that travel around the Sun in very elongated orbits. Some scientists even regard Pluto, the furthest planet from the Sun, as a large comet nucleus. Danny Faulkner explores the far reaches of our cosmic backyard in a hunt for clues to its age and origin.

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Design and Origins in Astronomy Volume 2

Astronomy and Creation: An Introduction

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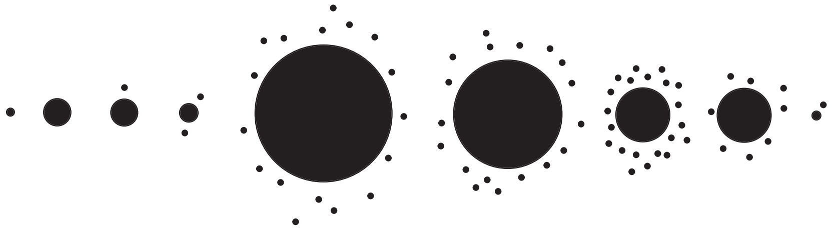
OUR SOLAR SYSTEM AND ITS ORIGIN

WAYNE R. SPENCER



Knowledge of our solar system has grown exponentially in recent years. Voyager, Clementine, Magellan, NEAR (Near Earth Asteroid Rendevous), Galileo, Mars Pathfinder, and the Mars Global Surveyor. These are names of NASA solar system missions over the past twenty years. Though not well known, the European Space Agency (ESA) has made significant contributions in solar system research over the past twenty years as well. The ESA also has missions planned for upcoming months and years that have great potential for significant scientific discoveries. The ESA mission Giotto was the first to take close up photos of a comet; the Giotto spacecraft flew by both comet Halley in 1986 and comet Grigg-Skjellerup in 1992. ESA operates three different missions currently that study the Sun and various solar phenomena that affect Earth. In 2005, after the Cassini spacecraft arrives at Saturn, a special probe built by the ESA called Huygens will be sent down into the atmosphere of Saturn's moon, Titan. Other possible future ESA missions include a mission to Mars, a mission to Mercury, one to the Moon to test a new solar-electric ion propulsion system, and a mission to orbit and land on a comet. Great resources in manpower and funding are required for all these missions, yet the science gleaned from these missions is biased by evolutionary presuppositions. However there are a few individuals with backgrounds in physics and astronomy who are young-age creationists interested in rethinking solar system issues from a creation perspective. What is a creation perspective on the solar system?

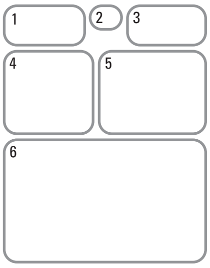
In the Bible, Romans 1:20 indicates that God's invisible qualities or attributes are evident to all people in the way things have been made. Much has been written regarding evidence for intelligent design in the living world. The complexity and purpose evident in living things points to an intelligent Creator. The attributes of the Creator are also evident from the non-living world. God's power, creativity, and purpose are evident in our solar system. Our solar system and our home planet are made to give us a safe stable existence. There has also been a great deal of research in recent years on the topic of extrasolar planets – planets orbiting other stars. Though a number of planets seem to exist around other stars, those solar systems are usually very different from our own (Spencer, 2001). In our solar system, not only has Earth been created so that it is an effective habitat for life, but there are other advantages to us on Earth from the way our solar system is arranged. For example, the size of our Moon and its distance from Earth are just right to allow for total eclipses of the Sun (Faulkner, 1998, p.23). Also, we now realize that Jupiter shields Earth from impacts from comets and asteroids because of where it is placed in our solar system.

Thus there are unique properties of our solar system that are for our benefit. Isaiah 45:18 in the NIV Bible says:

> "for this is what the LORD says—
> he who created the heavens,
> he is God;
> he who fashioned and made the earth,
> he founded it;
> he did not create it to be empty,
> but formed it to be inhabited".

TABLE 1.
Numerical data for the planets. Masses and diameters are compared to Earth. Here A.U. refers to Astronomical Unit, the distance from Earth to the Sun, which is approximately 93 million miles.

Name	Mass	Number of moons	Diameter	Distance from Sun in A.U.
Sun	333,266	-	109	-
Mercury	0.056	0	0.38	0.39
Venus	0.82	0	0.95	0.72
Earth	1	1	1	1
Mars	0.108	2	0.53	1.52
Jupiter	318	61	11.2	5.2
Saturn	95.1	31	9.41	9.5
Uranus	14.5	21	3.98	19.2
Neptune	17.2	11	3.81	30.1
Pluto	0.002	1	0.27	39.5



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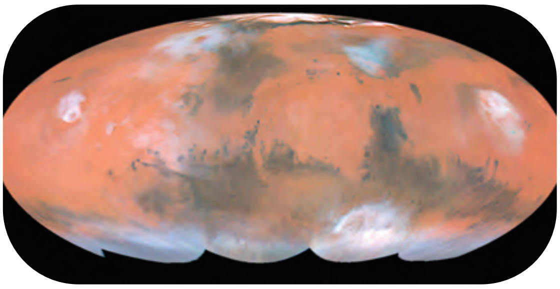

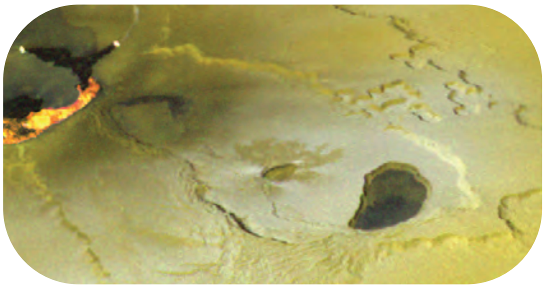

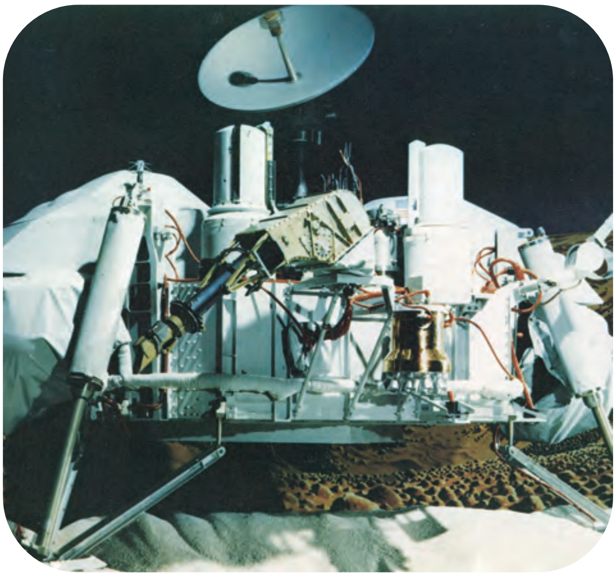

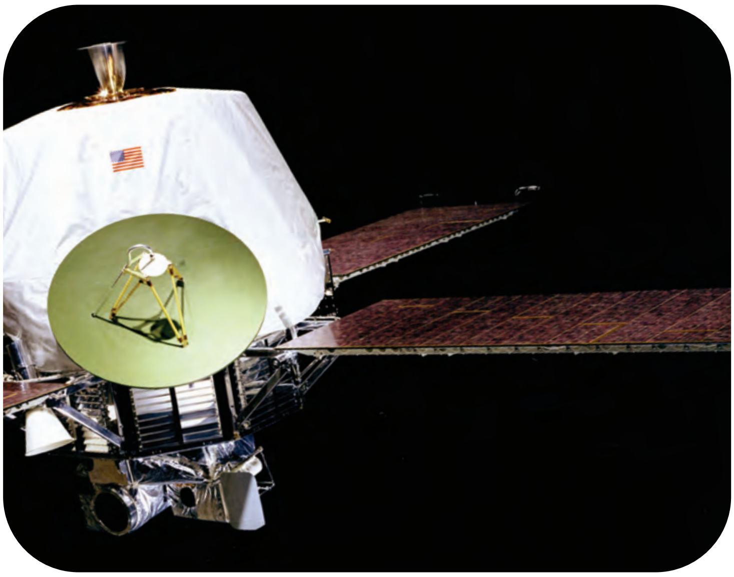

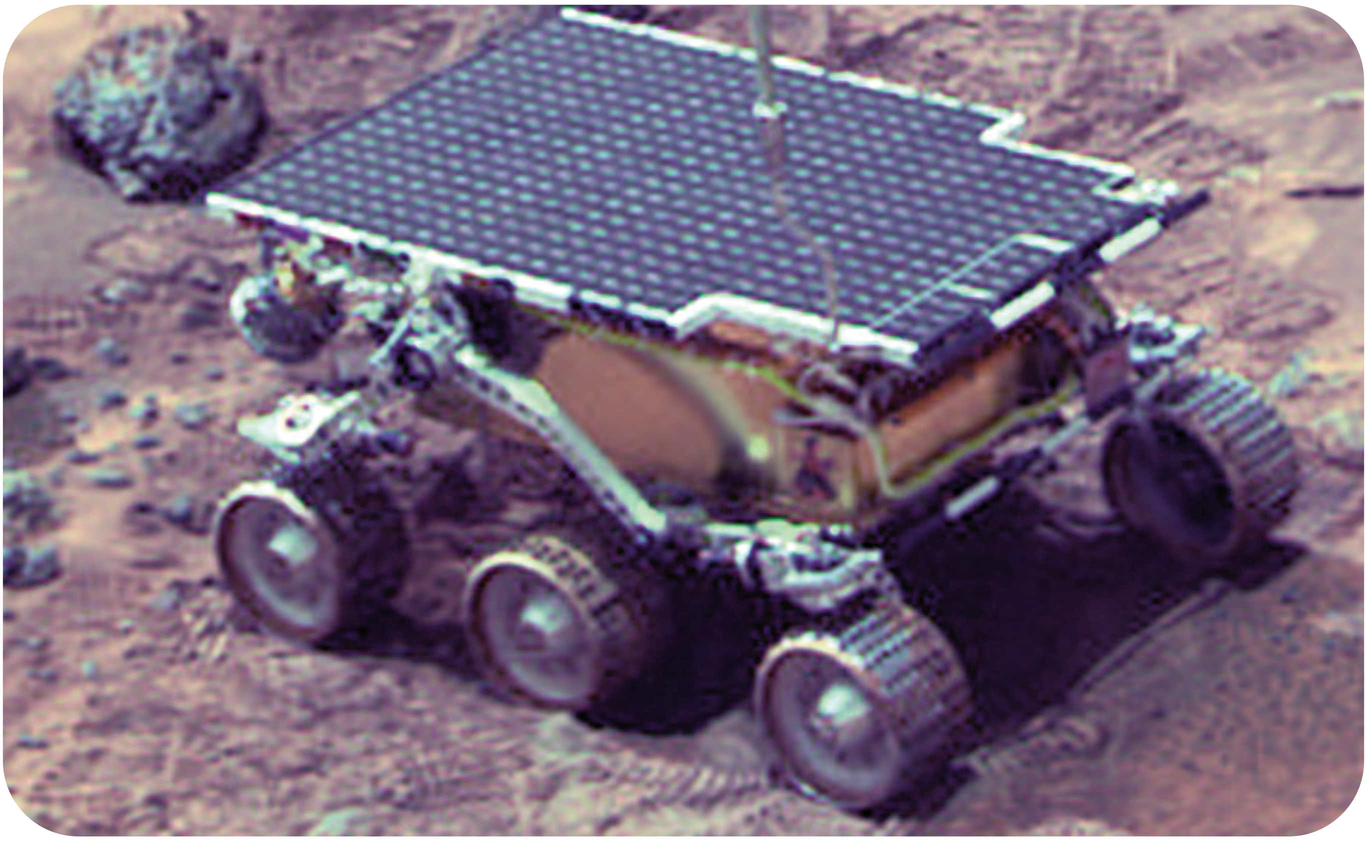

The Creator-God is not limited to the familiar environment we take for granted on Earth. He has made a variety in the planets and moons of our solar system, not to speak of the many thousands of smaller objects such as the asteroids, comets, and Kuiper Belt Objects found beyond Neptune. There are great extremes of conditions on these objects and features that have been very surprising to scientists. In today's accepted evolutionary approach to the origin of the solar system, all objects in the solar system are believed to have originally come from one cloud of gas and debris. Starting with this assumption leads to certain patterns being expected by planetary scientists when various solar system objects are studied. However, God is not limited to the naturalistic patterns predicted by evolutionary scientists.There have been many surprises as solar system missions have brought in the mountains of data. Many solar system origin problems have been researched for many years and yet there is still not a consensus on numerous issues, in spite of sophisticated modern methods.

In today's accepted naturalistic view of the origin of our solar system, supernatural creative activity by a Creator is not considered an option. Known processes of gravity, magnetism, chemistry, radioactivity are the primary processes involved in explaining how matter in a nebula in space could pull together to form our Sun, the planets, and all other objects in the solar system. This view is known as the Nebula Hypothesis. It is generally a very old idea but today there are many additions and modifications to the model to account for recent discoveries. Thus it could be called the Modified Nebula Hypothesis. However, there are some characteristics of solar system objects that do not lend well to them forming from a cloud of gas and dust.

A large nebula as observed in space is generally quite hot, hot enough to give off light, which is what allows us to see it. Such nebulae in space are much larger than our solar system and they are generally believed to have come from the explosion of stars (supernovae). As it cools, gravity would cause the nebula to contract and become more and more dense. In the Nebula Hypothesis, the nebula that is believed to have contracted to form our Sun is called the protosolar nebula. Such a cloud is rotating prior to its collapse, and as the cloud contracts by gravity, its spin would accelerate just like the spin of an Olympic ice skater pulling their arms in. As gravity continues to cause the cloud to contract, it would become a spinning disk of gas and dust. Matter is pulled to the centre and it is believed the gas in the centre would become dense enough for nuclear reactions to begin and then our Sun would begin generating energy as a star. As gravity pulls matter together, the gas begins to heat up, the rotation of the disk accelerates and this begins to push the material apart; magnetic forces can drive the material apart as well. Thus, one scientist, H. Reeves, referred to these as problems for explaining how the Sun and planets could form from the nebula. Reeves summarized the problems saying, "The clouds are too hot, too magnetic, and they rotate too rapidly" (Reeves, 1978, p.9). Many computer simulations of such processes have been done by physicists and astronomers. There are limitations of such models because the simulations either do not start with conditions like real nebulae or they do not model the entire process from a nebula in space to the complete formation of the Sun and planets. In the Nebula model, the gas eventually clears and you are left with a sheet of rocky and icy objects and dust. It is believed the dust and larger objects would stick together as they collided and this would lead to larger and larger objects forming over time. Large objects formed in this way would eventually become the planets. Though this type of scenario is widely accepted by scientists, there are reasons to suggest there is a limit to the size that objects could become by this process. So there are still unresolved issues about how planets could form by natural processes.

What are some of the difficulties with the Modified Nebula Hypothesis? One long-standing problem is with angular momentum. Any object in motion around the Sun has angular momentum and the spin of the object itself gives it additional angular momentum. If our Sun formed according to the Nebula Hypothesis, it would spin more and more rapidly as it contracted and the result would be a very rapidly spinning Sun. But, in our solar system we observe that the Sun spins very slowly and the planets move around the Sun relatively quickly. Our Sun makes one rotation on its axis, measured at its equator, in 24 days, 16 hours (Baugher, 1988, p.415). This slow rotation means the Sun possesses only about 2 percent of the total angular momentum of the solar system (Baugher, 1988, p.375). So the distribution of angular momentum doesn't fit the Nebula models well. In order to make it work, scientists have suggested magnetic processes that would slow down the Sun and accelerate the matter that became the planets. This is a very difficult problem for solar system theories. Since this problem has been worked on for years, one would think that it had been solved. But, a well known solar system scientist wrote that, "The ultimate origin of the angular momentum of the solar system remains obscure" (Taylor, 1992, p.53).

Other issues with the Nebula concept have arisen over what you could call 'irregular' properties of otherwise 'regular' objects. In the solar system there is a normal direction for motion, which can be remembered by using the right hand. With the right thumb pointing the direction of the North Pole of the Earth, for instance, the fingers of the right hand will curl in the direction of Earth's spin. This is the normal right-handed direction for both spins and orbital motions in the solar system. This is referred to as the prograde direction. Objects that either spin

> The Creator-God is not limited to the familiar environment we take for granted on earth

or revolve around the Sun in the opposite direction are referred to as moving retrograde. The rotation of the initial nebula dictates that the motions of all objects in the system would be in the prograde direction. But not all objects in the solar system move prograde. The planet Venus spins retrograde at a relatively slow rate, though its upper atmosphere spins very rapidly around the planet. Most of the planets have rotation axes that are not far from being perpendicular to the plane of their orbit. But Uranus and Pluto are exceptions as they both are oriented essentially on their side. Then there are many examples of moons in the solar system where either the orbital motion around the planet or the spin is retrograde. If an orbit is unusually elliptical it is considered ‘irregular’, as is an orbit where a moon moves retrograde around the planet. Various catastrophic and other scenarios have been suggested to explain the many examples of ‘irregular’ motion.

Orbital properties do not always reflect what planetary scientists assume from origins models. Triton, one of Neptune’s moons, has a very circular orbit, which is considered very ‘regular’ but Triton orbits in the retrograde direction, which is ‘irregular’. Because of this it is assumed that Triton did not originate where it is found now but was somehow captured by Neptune. Captured objects however must be captured into highly elliptical orbits. So, this raises questions about Triton’s origin and history that have not been fully answered. From a creation perspective, Triton could have been created in a circular retrograde orbit. From the point of view of the Nebula Hypothesis, this is not possible. At Jupiter many new small moons have been discovered in the past few years due to new observational techniques. Most of them orbit in the retrograde direction and they tend to be grouped in certain regions depending on their orbit inclination and distance from Jupiter. This suggests there may have been larger objects orbiting Jupiter in the past that were broken up by collisions (Sheppard and Jewitt, 2003, pp.261-263).

Our solar system displays certain regular patterns though some facts suggest catastrophic events have altered what God originally created. For example, there is a general tendency for planets nearer to the Sun to be made of higher density materials and planets farther from the Sun to be of lower density, more volatile substances. But, again, there are exceptions to this rule, as **TABLE 2** shows. Saturn and Pluto do not follow this pattern. Naturalistic nebula models for the origin of the solar system treat this relationship as due to the higher temperatures near the Sun than farther out, as the gas and dust in the disk was beginning to form planets. However, seeing this pattern as being from intelligent design is just as reasonable. The higher density, less volatile elements are more appropriate for the region nearer the Sun where temperatures are higher. If volatile gases, such as methane for example were present on Mercury they would only escape into space anyway. Thus there may be a design for stability in the density pattern. But God did not follow this pattern in a rigid manner.

The surfaces of planets and moons in our solar system bear indications of a violent history in many cases. Mars has a particularly dramatic geological history apparently. Mars has remnants of very large volcanoes, as well as large impact craters. There are also canyon systems, including Valles Marineris, which is long enough to stretch all the way across the continental United States. There seems to be indications of flooding in the past on Mars. This continues to be an enigma even today because Mars’ atmosphere and weak gravity would not allow it to hold an atmosphere that would sustain liquid water. If Mars had an atmosphere in the past, how did the atmosphere get there and how did it lose it? A large part of Mars’ surface in roughly the southern hemisphere is heavily cratered and this region is of higher elevation. But much of the northern hemisphere is smoother with dramatically fewer craters and of lower elevation. This is known as the crustal dichotomy and this continues to be a challenging mystery even with all the new detailed information on Mars from recent NASA missions.

TABLE 2.
Densities of the planets

Planet	Average Density (g/cc)
Mercury	5.43
Venus	5.25
Earth	5.50
Mars	3.93
Jupiter	1.33
Saturn	0.71
Uranus	1.24
Neptune	1.67
Pluto	2.0

In geology, young-age creationists often critique uniformitarianism, which holds that only presently observed processes are allowed for consideration in explaining Earth’s geological past (i.e., ‘the present is the key to the past’). However, since the Bible indicates there was a global Flood judgement on the Earth, catastrophic processes often explain Earth’s geologic features better than normal slow gradual processes. Many planets and moons show many indications of geological catastrophes as well as effects of impacts from space. But, uniformitarianism is often an evolutionary presupposition in solar system studies as well. Nobel prize-winning astronomer Hannes Alfven put it this way:

> *“This ‘actualistic principle’ which emphasizes reliance on observed phenomena, is the basis for the modern approach to the geological evolution of the Earth; ‘the present is the key to the past.’ This principle should also be used in the study of the solar system.” (Alfven, 1978, p.27).*

An example of where uniformitarian assumptions were very unsuccessful is the moon of Uranus known as Miranda. Miranda is a small moon less than 500 km in diameter. NASA mission planners were not particularly interested in Miranda because a small object cools off more rapidly and thus it was thought Miranda’s surface would be uninteresting. It was thought there should not be energy to drive dramatic geological processes so far from the Sun in such a small moon. However, two well known solar system scientists made the following comments about an unusual feature on Miranda known as the chevron (Chapman and Morrison, 1989, p.140):

> *"Even the earliest pictures of Miranda were enigmatic. From a distance, it looked as though some celestial giant had painted a big white checkmark on its surface, as if to say, 'Here's the answer!' Later called 'the chevron,' the immense check mark remains unexplained to this day."*

I prefer to call the "celestial giant" God. Miranda's surface has many strange surface forms, such as a cliff face which is nearly 10 miles in height! The solar system writers quoted above report a NASA scientist as making the following comment about Miranda's surface.

> *"If you can imagine taking all the bizarre geologic forms in the solar system and putting them on one object, you've got it in front of you." (Chapman and Morrison, 1989, p.140).*

There are various examples in the solar system of issues in which the challenge to the uniformitarian evolutionary approach is one of explaining how there could be energy for billions of years to drive processes we see evidence of. One type of example of this is in the very high speed winds measured in the gas giant planets, Jupiter, Saturn, and Neptune. The farther such a planet is from the Sun, the less energy is being input from the Sun to drive processes in the gases of the planet. So when wind speeds are found to be much higher than expected, it implies there is energy coming from the interior of the planet. This raises questions about the age of the planet and how there could be so much energy to drive such winds. If these planets are less than ten thousand years in age, it is easier to explain how there could still be energy for driving the winds today than if one assumes them to be billions of years in age.

Another example of a similar problem is Jupiter's volcanic moon Io. Io has several active volcanoes erupting at any given moment. These volcanoes are of a variety of types, some causing great explosions of sulphur compounds that soar high above the surface, and some eruptions generating very hot lava that flows out onto the surface. There are large amounts of heat radiating from the surface of Io; the rate would be approximately 100 million million Watts. Planetary scientists have experienced difficulty explaining how a small moon about the size of our moon could give off so much energy. It is known that Jupiter's gravity strongly heats Io from tidal forces flexing Io's shape similar to squeezing a rubber ball. But even this mechanism, known as tidal dissipation, is not an adequate source of heat. A young-age creationary approach simplifies the problem and suggests that heat is still left in Io from creation or possibly from a radioactive heating event in the past (Spencer, 2003).

Another area of research in which a young-age creationist approach has clear advantages over an evolutionary approach is regarding magnetic fields of planets and moons. Evolutionary scientists developed theories of what is called a dynamo to explain Earth's magnetic field. The dynamo theory has it that complicated motions of molten metal in Earth's core have sustained the magnetic field for Earth's alleged 4.6 billion years of history. Also, by the dynamo theory, Earth's magnetic field has undergone many long cycles of reversing polarity in Earth's history and the location of magnetic North has shifted significantly in the past. The dynamo model for Earth's magnetic field requires changes in the motion of the molten metal in the core that have not been adequately explained and there are various other difficulties with Earth dynamo theories. When planetary scientists have attempted to apply Earth-like dynamo models to other objects in the solar system, problems have been encountered (Parker, 1983, pp.44, 51-52).

Creationist physicist Dr. D. Russell Humphreys put forward a model of planetary magnetic fields that works well for both Earth and other objects in the solar system. Humphreys' theory is more flexible than dynamo models and can explain a wider range of types of planets and moons than can the dynamo model, which is based on evolutionary assumptions. Humphreys' approach assumed an age of roughly 6,000 years for Earth and the other planets. Humphreys suggested (1984) that there should be evidence on Mars of there having been a magnetic field there in the past from magnetized rock. In 1994 information was published from the Mars Global Surveyor mission indicating there were stripes of magnetized rock on Mars, even though Mars currently does not have a magnetic field (Connerney *et al*, 1994). There were other confirmations of Humphreys' magnetic field theories when the Voyager spacecrafts measured the magnetic fields of Uranus and Neptune. Both of these planets have odd magnetic fields that are tilted at least 50 degrees compared to the orientation of the planet. Humphreys' theory for planetary magnetic fields accurately predicted the approximate magnetic field strength of both Uranus and Neptune before the Voyager spacecrafts arrived at these planets (Humphreys, 1986; 1990). This is highly significant because dynamo theories require that there be molten metal in the core of an object and that the magnetic field be related to the object's rotation. In Humphreys' approach, the magnetic field could come from a solid metal core, not just a molten core. It also allows for a magnetic field to be in a very different orientation than the rotation axis of the planet.

There is so much new information about our solar system today that it will keep scientists busy for a long time to come as they try to unravel the meaning of it all. There are many problems in solar system studies that will be challenging for creationists as well as evolutionists. There has been significant discussion among creationists about the question of cratering in the solar system. When were the craters produced in our solar system? In the Creation Week, at the Fall of Man, at the time of Noah's Flood, or multiple of the above? This continues to be debated among creationists (Faulkner, 1999; Faulkner and Spencer, 2000; Froede, 2002; Froede and DeYoung, 1996; Spencer 2002). As Christians it is important to realize there are options to be explored for rethinking and re-explaining the science of origins in the light of new discoveries. We do not have to compromise on our biblical convictions.

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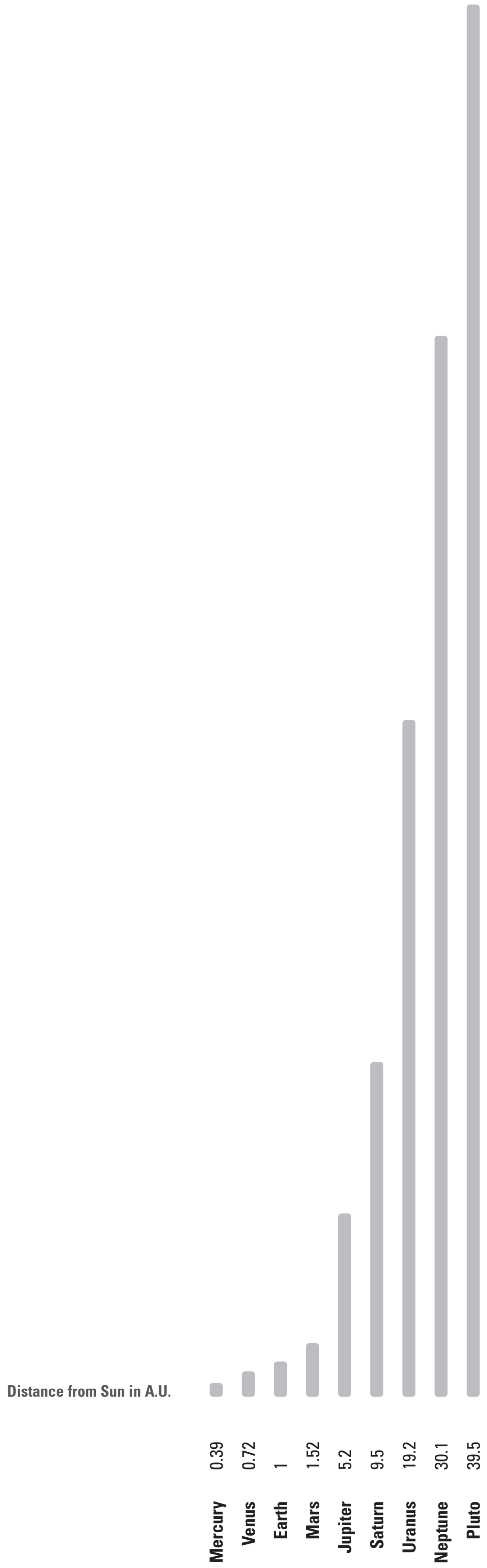
Relative distances of planets from Sun



THE SUN – THE GREATER LIGHT TO GOVERN THE DAY

WILLIAM J. WORRAKER

> "God made two great lights – the greater light to govern the day and the lesser light to govern the night.
>
> He also made the stars.
>
> God set them in the expanse of the sky to give light on the earth, to govern the day and the night, and to separate light from darkness.
>
> And God saw that it was good." (Genesis 1:16-18)

Introduction

We can readily identify "the greater light to govern the day" in the passage on the right as the Sun since its presence in the sky determines the hours of daylight, and its altitude above the horizon determines how much of its heat is available to warm the Earth. Physically, the Sun is a huge ball of incandescent gas (mostly hydrogen and helium), 109 times larger than the Earth in diameter and over 330,000 times more massive. It is a very important object, most obviously because it provides the heat and light necessary for life on Earth. Less obviously, its energy output and distance from the Earth are closely tuned to the needs of living creatures; a hotter, more distant Sun would produce more ultraviolet light and so inhibit photosynthesis in plants, while a cooler, closer Sun would produce too much infra-red and not enough visible light for efficient photosynthesis. The Sun's heat drives the circulations of the atmosphere and oceans which give rise to weather and climate and to the water cycle, which is also vitally important for life. Furthermore the Sun's gravity keeps the planets of the solar system moving round in stable orbits. In conjunction with the daily rotation of the Earth and the tilt of its axis, this means that the Sun gives rise to the cycle of day and night and the seasons which regulate life on Earth. Hence the Sun plays a key role in the delivery of God's promise in Genesis 8:22, "As long as the earth endures, seedtime and harvest, cold and heat, summer and winter, day and night will never cease."

The Sun affects us in less obvious ways too. For example, the beautiful coloured light displays often seen in the night sky in high latitudes – the *Aurora Borealis* in the northern hemisphere and the *Aurora Australis* in the southern hemisphere – are the result of charged particles from the Sun interacting with the Earth's magnetic field, as discovered by the Norwegian scientist Kristian Birkeland early in the twentieth century. Moreover short-wave radio communications can be disrupted and artificial Earth satellites knocked out of action as a result of huge quantities of gas being hurled across space by the Sun. Such eruptions have even caused national power grids to fail on occasions! Another, relatively subtle, effect of the Sun is in regulating ocean tides. The tides are caused by the gravitational pull of the Moon, but at any one place the total rise and fall of water is largest when the Sun, Earth and Moon are in line (at New Moon and at Full Moon) – *spring tides* – and smallest when these bodies form a right angle (at First Quarter and at Last Quarter) – *neap tides*. Other effects can be cited, but the above serve to illustrate how the Sun influences life on Earth.

For astrophysicists the Sun is vitally important because it is the closest star, and we can study it in far more detail than any other star. Thus our

TABLE 1.
The data in this table are based on the NASA solar physics website at http://science.nasa.gov/ssl/pad/solar/default.htm, except for the items marked †, which are taken from The Handbook of the British Astronomical Association 2004 *(British Astronomical Association ISSN 0068-130-X, October 2003).*

Property	Value	Unit
Distance from earth	150 million	km (kilometre)
Radius	695, 990 109	km Earth radius
Mass	1.989×10^{30} 333,000	kg (kilogram) Earth mass
Surface temperature	5770	K (kelvin)
Central temperature	15.6 million	K
Surface density	2.07×10^{-4}	kg/m^3 (kg/cubic metre)
Central density	150,000	kg/m^3
Energy output	3.846×10^{26}	W (watt)
Equatorial rotation period †	25.38	day (sidereal, i.e. measured against the stars)
Axial tilt †	7.25	degree (from the normal ecliptic)
Surface composition	70% H, 28% He, 2% heavier elements	mass-based percentage

understanding of the Sun is the key to understanding stars in general, and it is customary to use the Sun as the standard of comparison for other stars. Hence the sizes, masses, luminosities and other properties of stars are usually (and very conveniently) measured in solar units.

TABLE 1 (P.11) lists the values of some basic properties of the Sun.

Structure and Features

FIGURE 1 (P.14) is a cutaway view of the Sun showing the various zones into which it can be divided. Note that the *photosphere* corresponds to its visible surface, which implies that the zones inside the photosphere (*core*, *radiative zone*, and *convective zone*) cannot be observed directly. Rather their existence and properties have been deduced from models of the Sun's interior informed by observations of its total mass (which in turn is deduced from the movements of the planets), its energy output, its composition (which is based on spectroscopy, the detailed analysis of its light), and its surface activity and surface features. In the relatively static radiative zone energy is transported outwards by the diffusion of photons, while in the convective zone it is carried by fluid convection like the circulation of water in a saucepan heated from below (see **FIGURE 2**, P.14). High-resolution images of the photosphere readily show granulations marking the tops of convection cells; these are typically 1,000 kilometres across and last for only 5-10 minutes. An important source of information about the Sun's core lies in the flow of *neutrinos*, the extremely elusive, almost massless particles which are produced in the fusion reactions believed to power the Sun's prodigious output of energy.

Outside the photosphere lie the *chromosphere* and the corona. The chromosphere is an irregular layer immediately above the photosphere, and can be seen in detail in the red light of neutral hydrogen (*H-alpha*), or the violet light of singly ionized calcium (*the calcium K-line*). The temperature rises from approximately 6,000°C at the photosphere to 20,000°C through the chromosphere. The corona is very thin but extremely hot (its temperature is typically well over 1 million K) and radiates mostly at extreme ultraviolet and X-ray wavelengths. It becomes visible during total solar eclipses (see **FIGURE 3**, P.14).
It has a beautiful, delicate filamentary structure which traces the Sun's external magnetic field, and shows a variety of features – streamers, plumes, loops and sometimes huge, dark *coronal holes*. A long-standing scientific puzzle is the question of how the corona is heated, given that it is much hotter than the chromosphere. The explanation nowadays in favour is that energy is constantly being injected from below by electric currents and by shock waves due to explosive magnetic events such as flares. However, coronal heating is still very much an active research topic.

The corona is so hot that the Sun's gravity cannot completely hold on to it. This produces the *solar wind*, a stream of charged particles which moves at speeds of hundreds of kilometres per second outwards through the solar system, eventually stopping at the *heliopause*, which lies in interstellar space well beyond the orbit of Pluto. The solar wind and its variations (due to flares and coronal mass ejections) are responsible for aurorae, the Van Allen radiation belts around the Earth, the movements of comet tails, and for various other phenomena which may be grouped together under the title 'space weather'. Such space weather has to be taken into account in the design and operation of artificial Earth satellites and spacecraft.

The Sun is nearly spherical in shape because it is so massive that its gravity forces it into the most compact three-dimensional shape possible – a sphere. However it is slightly oblate (flattened) because of its rotation. It does not rotate as a solid body, taking 25 days for a complete rotation at the equator and around 30 days at the poles. Its rotation is most easily noticed by observing the daily movement of the darkish spots known as *sunspots* which are frequently seen on its surface. Sunspots usually appear in pairs, often in groups, and their overall frequency varies on an approximately 11-year cycle discovered by the German amateur astronomer Heinrich Schwabe in 1843. Sunspots are due to magnetic field loops penetrating the solar surface, which is why they are often seen in pairs known as *active regions*. Sunspots are both darker and cooler than their surroundings because the magnetic field suppresses convection and hence locally reduces the flow of heat to the surface. Thus the 11-year sunspot cycle is really a *magnetic activity cycle*.[1] **FIGURE 4** (P.14) shows a typical image of the Sun with groups of sunspots visible, while **FIGURE 5** (P.14) shows a close-up of a sunspot surrounded by granulations and **FIGURE 6** (P.14) shows a magnetic field loop marked by hot gas above an active region.

The Sun's extremely complex magnetic field, which is responsible for a wide range of phenomena in addition to sunspots, is due to electric currents which can flow easily there because the gas is so hot that its atoms have lost some or all of their electrons, i.e. they are *ionized*. The source of energy for these currents and their associated magnetic fields probably lies in the interaction between rotation and convection, which produces a *dynamo effect*, probably seated at or near the base of the convective zone. Blobs of fluid carrying magnetic field generated in this way will naturally rise to the surface. As they break the surface various phenomena arise in addition to sunspots, e.g. *faculae, plages*, *spicules*, and *filaments*, which are normally viewed in red H-alpha light. *Prominences* are huge magnetically-supported jets or clouds of gas suspended above the photosphere; they are often seen or photographed during solar eclipses (see **FIGURE 3**, P.14). They can occasionally erupt into space in minutes as a result of changes in the supporting magnetic field. The most dramatic phenomena associated with the Sun's magnetic field are *flares* and *coronal mass ejections*. Flares are huge explosions caused by a highly stressed magnetic field as it suddenly snaps into a simpler, lower-energy arrangement above sunspots (see **FIGURE 7**, P.14). A solar flare can generate the energy equivalent of up to a billion megatons of TNT, heating local gas to millions of degrees, producing floods of gamma rays, X-rays and energetic charged particles (electrons and protons) as well as hurling masses of gas into space. Coronal mass ejections are huge bubbles of gas threaded by magnetic field lines which erupt from the Sun over the course of several hours. They can sometimes expand to become larger than the Sun itself. They are usually, but not always, associated with flares or prominences. Coronal mass ejections disturb the solar wind and can strike the Earth with the damaging effects on telecommunications, artificial satellites and power grids mentioned earlier.

Scientists studying the internal structure of the Sun glean a lot of information from *helioseismology*. This is the solar equivalent of seismology, the study of vibrations due to earthquakes which Earth scientists use to investigate the internal structure of the Earth. The Sun, being essentially a gas sphere, is subject to a variety of oscillatory disturbances most probably caused by convection and magnetic field activity on or near its surface. Its oscillations are known as *p modes* (sound waves), *g modes* (internal gravity waves) and *f modes* (surface gravity waves); p modes and g modes are illustrated schematically in **FIGURE 1** (P.14). In particular, SOHO (Solar and Heliospheric Observatory, a joint ESA/NASA project)[2] and GONG (Global Oscillation Network Group, a US National Solar Observatory project)[3] have recently been set up to monitor the modes of oscillation of the Sun's surface in great detail. Measurements of the strengths and periods of oscillation of millions of p modes (which are generally strongest when their period lies between 3 and 8 minutes) have helped considerably to refine models of the Sun's interior. Beyond this, helioseismic data also allows solar physicists to map rotation patterns inside the Sun, and some surprising effects have been discovered as a result. For example, there is a surface layer 50,000 km thick which rotates more slowly than the deeper interior; so far no-one has explained how this can happen. Furthermore blobs of material containing strong magnetic field rise through the convective zone in an unexpected manner; rather than expanding by a large factor near the surface, they emerge as a collection of strong, small bundles. Thus helioseismology has proved to be a very powerful tool for probing the Sun's interior, and it has not only clarified some questions but also raised other, very intriguing ones which currently remain unanswered.

Origin and Age

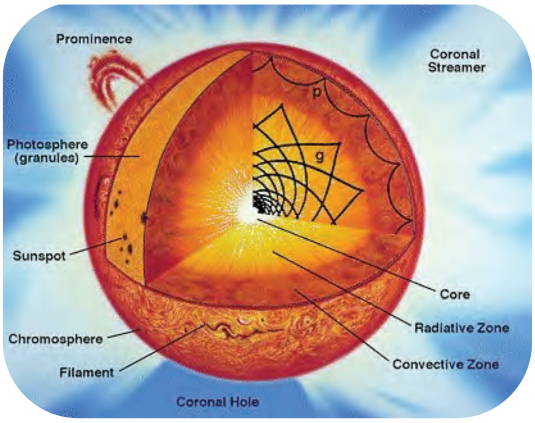
We are particularly interested here in knowing how old the Sun is, and how it came into being. Textbooks usually say that its age is quite precisely known at about 4.6 billion years and that it was formed out of a rotating cloud of gas and dust which collapsed under its own gravity. The Earth and the remaining objects in the solar system (i.e. the other planets and their satellites, the asteroids, and the more remote objects of the Kuiper Belt) are believed to have formed out of the same collapsing cloud. This account assumes that the origin of the solar system *must* be explained in terms of pre-existing material subject to recognised physical processes; miraculous divine activity is ruled out. This approach also rules out any purpose or design associated with the Sun.

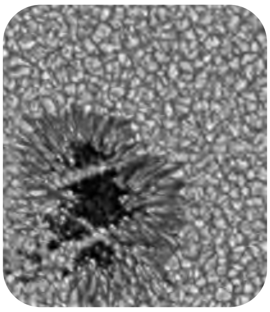
All this contrasts sharply with a straightforward reading of Genesis 1, which implies that the Earth was created with its oceans about 6,000 years ago, followed by the land masses, plant life and then the Sun, Moon and stars (the latter almost certainly including the planets), all within a time span of four days. The biblical account implies that, from the day it was created, the Sun was a fully functioning source of heat and light for the Earth – it was purposefully provided by the Creator. Furthermore, just as Adam was created a man rather than a baby, so the Sun was created a 'mature' star, with fully operational heat generation and transport mechanisms. We call this the principle of *apparent age* in creation. We may expect to find many examples of apparent age in a fully-functional created order.

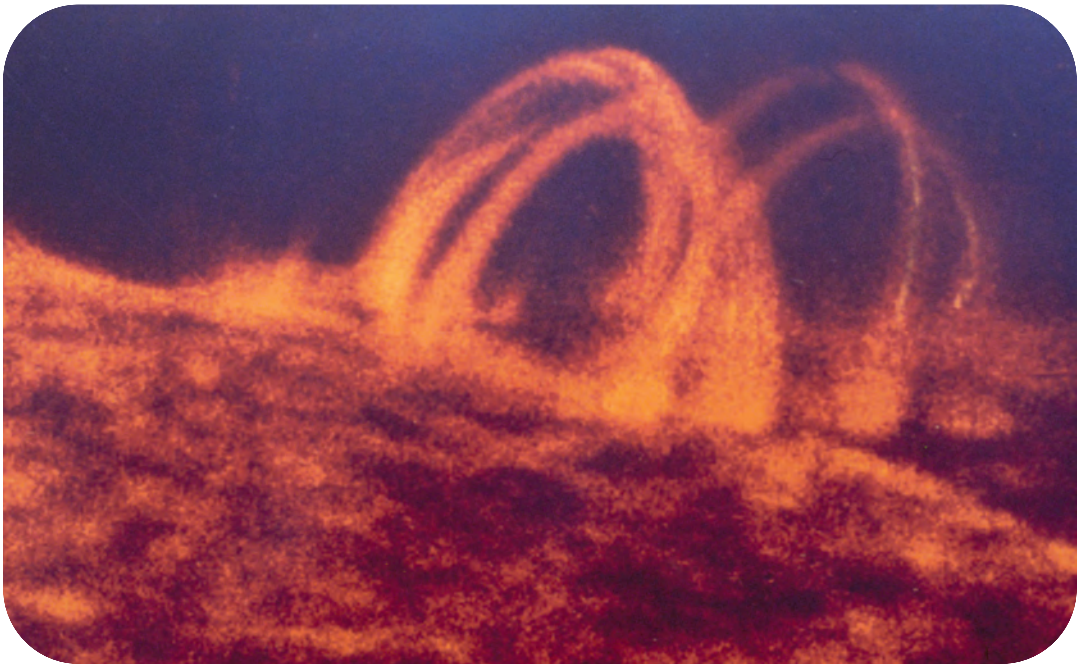
Is there any evidence to decide between these sharply conflicting accounts of the Sun's origin? Its visible surface changes incessantly and so retains no direct evidence of its history. The photons generated in the core may, according to standard solar models, take millions of years to cross the radiative zone, but this does not necessarily mean that the sunlight we observe today came originally from the Sun's core millions of years ago. By the apparent age principle it could equally well have started from near the outer boundary of the radiative zone about 6,000 years ago. However, recent observations imply that energy is generated in the Sun's core at a rate which balances the energy it radiates into space. This balance or stability in the Sun's behaviour is critical for the well-being of life on Earth. From a biblical perspective involving an apparent age for the Sun, it demonstrates God's providential care for his creatures.

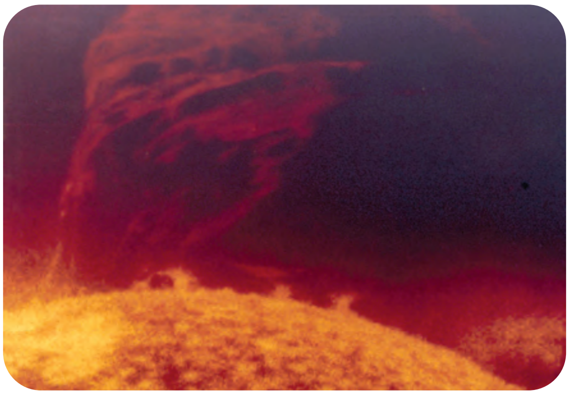
Another important question is the source of the Sun's energy. If the Sun has been producing energy at anything like the observed rate for billions of years, it must have a power source able to last that long. The only recognised candidate today is nuclear fusion; other proposed sources, e.g. gravitational contraction, would be exhausted within a much shorter time. Hence recent observations of a neutrino flux matching expectations mean that nuclear fusion almost certainly accounts for practically the entire present-day solar energy budget, and that it *could* have powered the Sun for 4.6 billion years. However, neutrino observations do not *demand* that the Sun has been around for so long with fusion taking place in its core; this could simply be another instance of apparent age. Note that observations to date only relate to neutrinos with energies above 5 MeV (million electron volts); over 99.99% of the total expected flux of solar neutrinos is below this energy (Bahcall, 2002). Since, therefore, the vast majority of solar neutrinos remain unsampled, we should perhaps hesitate to claim that solar neutrino physics is now fully understood and all problems resolved.

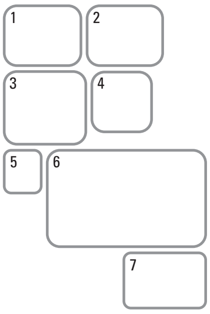
The Sun's rotation is at the heart of a key argument concerning its origin. Although the Sun contains 99.9% of the mass of the solar system, it contains only about 1% of its angular momentum[4] – most of the remainder is associated with Jupiter. According to Carroll and Ostlie (1996, pp.890-891), this distribution of angular momentum "...has frustrated most attempts at developing an adequate picture of how the solar system developed..." The same authors continue: "To complicate matters further, the Sun's spin axis is tilted 7 degrees with respect











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to the average angular momentum vector of the planets.” It is very hard to envisage how the Sun’s spin axis could have become misaligned to this extent; for example, a close encounter with another star is hardly likely to leave the planets orbiting the Sun in the orderly manner we observe. The evolutionary paradigm clearly has major problems in explaining how the Sun came to rotate as it does. There are no such problems for the biblical account of its origin.

How can we decide on the true age of the Sun? Consider its presumed evolution as it consumes its nuclear fuel over billions of years, specifically the ‘burning’ of hydrogen to helium in its core. Standard solar models predict that the Sun’s energy output has increased by about 40% since the assumed formation of the solar system 4.6 billion years ago. Thus 3.8 billion years ago when, according to evolutionary scientists, life was starting to appear on Earth, the Sun would have been about 25% fainter than at present (Carroll and Ostlie, 1996, p.383, Fig. 11.2). The Earth should have become warmer since that time. Faulkner (2001) has calculated a minimum temperature rise of 18°C in the last 3.8 billion years, which implies that the average sea-level temperature was then no higher than -3°C. In Faulkner’s words, “Thus when life supposedly was just beginning, much of the Earth would have been frozen”. Note that this does not refer to the highly contentious ‘Snowball Earth’ idea (Oard, 2002), which has not been invoked by evolutionary scientists for any period before 2.5 billion years ago.

However geological evidence does not support the idea that the Earth was much colder so far back in its history; if anything, it was warmer than now. *Ad hoc* attempts have been made by evolutionary scientists to explain this discrepancy, including (i) a more massive early Sun which subsequently lost mass,[5] (ii) enhanced levels of atmospheric carbon dioxide or methane,[5] and even (iii) a collision-induced 70° tilt of the Earth’s axis.[6] No independent evidence supports any of these suggestions. Furthermore, evidence from Mars suggests that, 3.8 billion years ago on the same evolutionary time scale, Mars was considerably warmer and wetter than it is now. Thus even if we can imagine a delicate feedback between gradually increasing solar heating and an evolving biosphere on Earth which could have kept the temperature roughly constant over billions of years, it is extremely hard to see how Mars could have been relatively warm when the Sun was relatively cool. The simplest way to resolve this paradox is to accept that the Sun, and indeed the rest of the solar system, is no more than about 6,000 years old as indicated by the biblical account.

Solar eclipses also have a bearing on our view of the origin of the Sun. Even in the twenty-first century people find total eclipses of the Sun an awe-inspiring spectacle, and there is now a significant tourist industry built around eclipse-watching. Such eclipses are also valuable scientifically, allowing observations of the Sun’s corona which are hard to obtain at any other time; although continuous observations can be made from spacecraft such as Yohkoh and TRACE (Transient Region and Coronal Explorer), ground-based observations made during eclipses can often yield more detail, especially in the key innermost region of the corona. For such eclipses to occur, the Sun and Moon must have approximately the same angular size as seen from Earth, which demands a finely-tuned combination of distances and dimensions for the Sun and Moon. This is unlikely to occur by chance (Faulkner, 1998). Thus we are entitled, I believe, to view this spectacular natural phenomenon as an example of the generosity of the Creator, both in aesthetic and scientific terms. If we are willing to think biblically, solar eclipses should cause us to glorify our Creator.

Conclusions

We have briefly surveyed the Sun’s observed characteristics and some key issues surrounding its age and origin. My first conclusion is that the Sun is a truly fascinating as well as an important object, a reflection, perhaps, of the character of the Creator. Although much has been learnt about it in recent years, there is still much for us yet to learn. Secondly, quite contrasting views of its origin are possible, which may be termed the *naturalistic* and *biblical* views. The naturalistic view measures the age of the Sun in billions of years, the biblical view in thousands of years. Many observed features (e.g. its dynamic surface activity, the neutrinos produced in its core, etc) are consistent with either view. However at least two lines of evidence favour the biblical view, viz. the problem of how the Sun came to rotate as it does, and the ‘young faint Sun’ paradox. Furthermore, many of the Sun’s characteristics, e.g. its surface temperature and distance, its relative stability, the occurrence of solar eclipses etc, are readily understood as the gracious provision of a loving Creator as described in the Bible.

NOTES

1. The pairs of spots in active regions are usually oriented east-west. Their magnetic polarity is opposite in the Sun’s northern and southern hemispheres. These polarities reverse direction every 11-year cycle (i.e. between successive times of minimum sunspot activity). Thus the underlying magnetic activity cycle really has a 22-year period.

2. See http://sohowww.nascom.nasa.gov/ (downloaded 26 June 2004).

3. See http://gong.nso.edu (downloaded 26 June 2004).

4. Angular momentum is used by physicists to measure the effort required to stop a rotating body.

5. See the University of Bristol (Earth Sciences) website at: http://pc10.gly.bris.ac.uk/Seds/atmosph/Final/Weak_sun/the%20front%20cover.html (downloaded 26 June 2004).

6. See the Penn State University website at: http://www.rps.psu.edu/0105/world.html (downloaded 26 June 2004).

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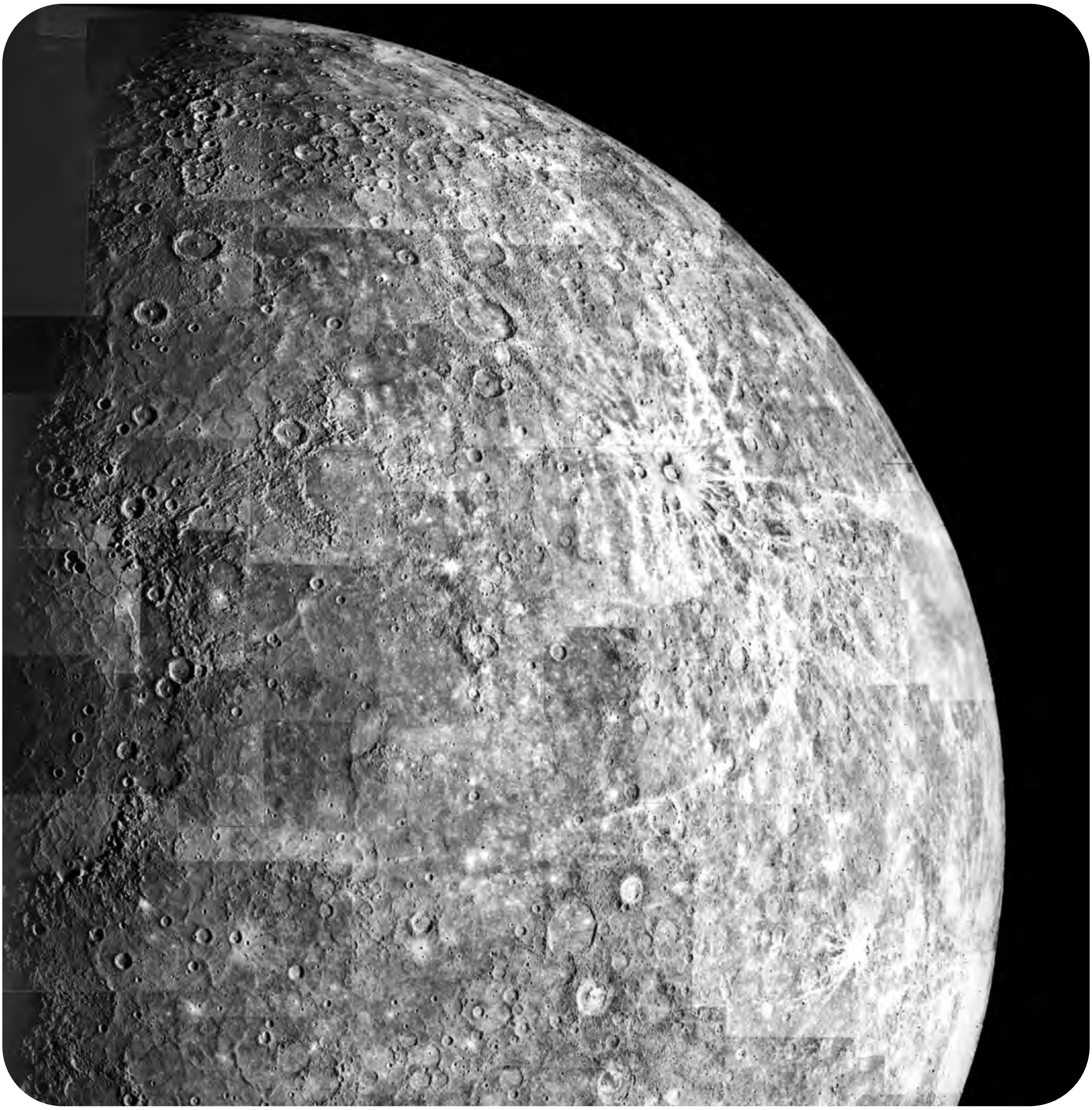

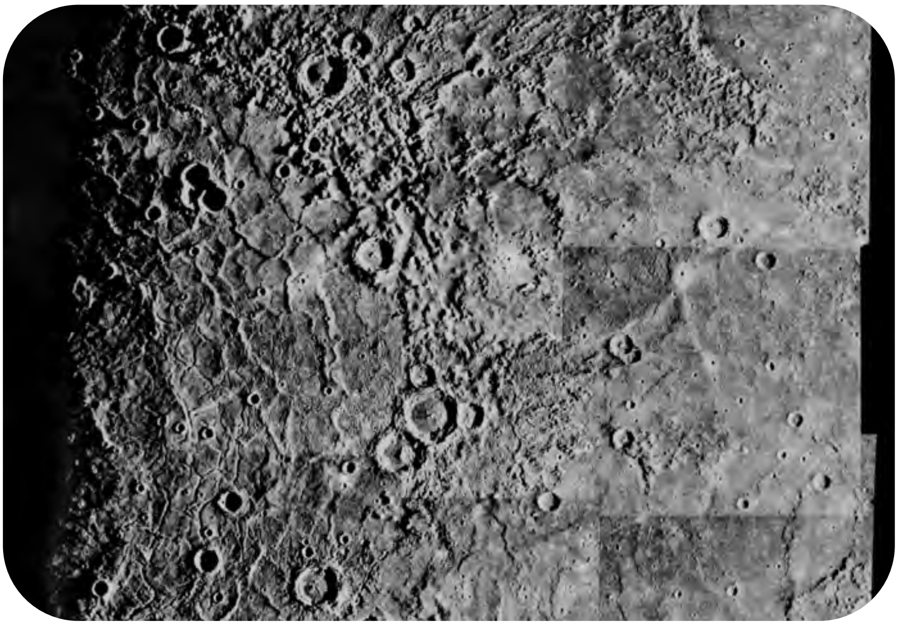

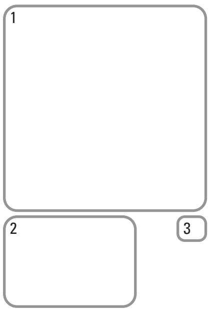

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MERCURY – THE PLANET OF MYSTERY

J. H. JOHN PEET

No doubt many people have imagined travelling in a space ship to another planet such as Mars. Few would contemplate turning the ship around and heading towards the Sun and visiting the planet Mercury. It is the closest planet to the Sun. Its elliptical orbit takes it to within 29 million miles of the Sun, 44 million miles at its most distant point. It needs little imagination to realise that it would be a scorcher of a visit! But consider also the problems of the technology: a vehicle to withstand the high temperatures and able to maintain communication with Mission Control in spite of the heavy solar radiations! That explains why little research has been done into this planet. Mariner 10 visited it in 1974/1975 (and photographed less than 50% of the planet) and future visits are planned. So, what do we know about it?

Observations of the planet from Earth are difficult because it is always within 27° of the Sun (that's equivalent to the Sun at 12 o'clock and the planet at 1 o'clock on a clock face) and can only be viewed at twilight.

It is the fastest-moving planet and it would seem that it was named after the Roman god which was marked out for its swiftness of movement. The planet's axis is almost perpendicular to its orbit, so there are regions where the Sun never shines. As a result, ice deposits can be found in the polar regions. But, there is no adequate evolutionary explanation of the origin of this ice.

The length of the day on Mercury is equivalent to 176 Earth-days and its year is equivalent to 88 Earth-days![1] Because of the slow rotation of the planet, the daytime temperature rises to over 400°C and drops to below -150°C at night. It has a thin atmosphere which originates from the solar wind. This atmosphere has to be replenished in a short time because of the low surface gravity which allows the gases to reach their escape velocity.

The surface of the planet is marked with craters giving it an appearance similar to Earth's Moon (Mercury does not have a moon of its own). Like many other planets in the solar system, it was the victim of an asteroid bombardment four billion radioactive-years ago. This damaged the surface, generated sufficient heat to melt the surface rocks and released lava beneath the surface. One impact formed a basin, Caloris, over 800 miles across, over a quarter of the planet's diameter! The force of the impact apparently cracked the surface on the opposite side of the planet! These impacts are of interest to creationists because most of the effects on Earth disappeared (the Hadean rocks) and were replaced by the Archaean. It is possible that this asteroid bombardment was the initiation of the Flood described in Scripture as the opening of the "windows of heaven". The equivalent impacted rocks have been identified on the Earth's moon and on Mars. There are surface cracks on Mercury that suggest the planet may have shrunk, perhaps as the interior cooled.

There are some other puzzling features about the planet. For example, the planet has a magnetic field. This has suggested that the core is liquid iron generating a dynamo effect. There are problems, though, with this. Dynamo action seems to be unlikely in view of Mercury's slow rotation. The idea of a liquid iron core is supported by the high density of the planet (similar to Earth), but there is no trace of iron in the surface rocks. The lava flows mentioned above would cause us to expect it. But, such a core is inconsistent with the small size of a planet with such an age as that proposed by the evolutionary model. The core should have solidified by now. It is suggested by some evolutionary scientists that the magnetic field would have 'frozen in' this solid core, but we may question why this has not decayed to a very low field strength after billions of years.

As we have indicated, it is generally believed that lava flows are responsible for a number of Mercury's features. However, typical volcanic characteristics are missing (such things as flow lobes, domes and cones).

Clouds of sodium and potassium metal vapours have often been observed on the planet's surface. Though these discharges vary over time, they do suggest that the planet might still be warm inside, allowing these metals to vaporize.

The field evidence leaves us with many unanswered questions. In fact, one of the foremost researchers into this planet commented recently, "Its extreme properties make Mercury difficult to fit into any general scheme for the evolution of the solar universe" (Nelson, 2003). For the creationist, it is just another example of the Creator's delight in diversity!

NOTE

1. This arises because the rotation period is 58.6 Earth-days with respect to the stars, which is precisely 2/3 of its year. This in itself is a challenge to evolutionary explanations as they would predict a 2:1 ratio rather than 3:2.

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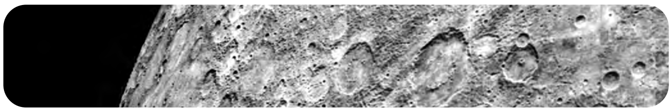
Mercury data file



Average distance from the Sun	0.387 A.U. (5.79 x 10^7 km)
Eccentricity of orbit	0.2056
Maximum distance from the Sun	0.467 A.U. (6.97 x 10^7 km)
Minimum distance from the Sun	0.306 A.U. (4.59 x 10^7 km)
Inclination of orbit to ecliptic	7º00’16”
Average orbital velocity	47.9 km/s
Orbital period	0.24085 y (87.969 days)
Period of rotation	58.646 days (direct)
Inclination of equator to orbit	0º
Equatorial diameter	4,878 km
Mass	3.31 x 10^{23} kg
Average density	5.44 g/cm^3
Surface gravity	0.38 Earth gravity
Escape velocity	4.3 km/s
Surface temperature	-170ºC to 430ºC (-280ºF to 800ºF)
Average albedo	0.1
Oblateness	0

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Venus data file

Average distance from the Sun	0.7233 A.U. (1.082 x 10^8 km)
Eccentricity of orbit	0.0068
Maximum distance from the Sun	0.7282 A.U. (1.089 x 10^8 km)
Minimum distance from the Sun	0.7184 A.U. (1.075 x 10^8 km)
Inclination of orbit to ecliptic	3º23’40”
Average orbital velocity	35.03 km/s
Orbital period	0.61515 y (224.68 days)
Period of rotation	243.01 days (retrograde)
Inclination of equator to orbit	177º
Equatorial diameter	12,104 km
Mass	4.870 x 10^{24} kg
Average density	5.24 g/cm^3
Surface gravity	0.903 Earth gravity
Escape velocity	10.3 km/s
Surface temperature	745 K (472ºC, or 882ºF)
Average albedo	0.76
Oblateness	0

Seeds, M.A. (2001). Astronomy: The Solar System and Beyond*. Second Edition. Brooks/Cole, Pacific Grove, California.*

Earth data file

Average distance from the Sun	1.00 A.U. (1.495979 x 10^8 km)
Eccentricity of orbit	0.0167
Maximum distance from the Sun	1.0167 A.U. (1.5210 x 10^8 km)
Minimum distance from the Sun	0.9833 A.U. (1.4710 x 10^8 km)
Inclination of orbit to ecliptic	0º
Average orbital velocity	29.79 km/s
Orbital period	1.00 y (365.25 days)
Period of rotation (with respect to the Sun)	24h 00m 00s
Inclination of equator to orbit	23º27′
Equatorial diameter	12,756 km
Mass	5.976 x 10^{24} kg
Average density	5.497 g/cm^3
Surface gravity	1.0 Earth gravity
Escape velocity	11.2 km/s
Surface temperature	-50ºC to 50ºC (-60ºF to 120ºF)
Average albedo	0.39
Oblateness	0.0034

Seeds, M.A. (2001). Astronomy: The Solar System and Beyond. *Second Edition. Brooks/Cole, Pacific Grove, California.*

Mars data file

Average distance from the Sun	1.5237 A.U. (2.279 x 10^8 km)
Eccentricity of orbit	0.0934
Maximum distance from the Sun	1.6660 A.U. (2.492 x 10^8 km)
Minimum distance from the Sun	1.3814 A.U. (2.066 x 10^8 km)
Inclination of orbit to ecliptic	1º51′09″
Average orbital velocity	24.13 km/s
Orbital period	1.8808 y (686.95 days)
Period of rotation	24h 37m 22.6s
Inclination of equator to orbit	25º19′
Equatorial diameter	6,796 km
Mass	0.6424 x 10^{24} kg
Average density	3.94 g/cm^3
Surface gravity	0.379 Earth gravity
Escape velocity	5.0 km/s
Surface temperature	-140ºC to 20ºC (-220ºF to 68ºF)
Average albedo	0.16
Oblateness	0.009

Seeds, M.A. (2001). Astronomy: The Solar System and Beyond*. Second Edition. Brooks/Cole, Pacific Grove, California.*

THE GOLDILOCKS PLANET – THE EARTH COMPARED WITH MARS AND VENUS

DANNY R. FAULKNER

Mars and Venus are more like the Earth than any of the other planets. The similarities include distance from the Sun, size, mass, and composition. All three planets have atmospheres, though Venus' atmosphere is far denser than the Earth's, and the atmosphere of Mars is much less dense than the Earth's. Because of their similarities to the Earth, many astronomers during the twentieth century thought that Mars or Venus might be places where life could exist. The very thick clouds on Venus suggested the presence of water there, and at one time scientists entertained the possibility that the surface of Venus might have a tropical climate. However, hope for life on Venus was dashed once we discovered that the thick clouds contained almost no water and that the extreme greenhouse effect on Venus rendered a hellish, hostile environment on the surface. The huge amount of carbon dioxide (CO_2) present in the Venusian atmosphere is responsible for the hottest surface temperature of any planet in the solar system, even hotter than Mercury, even though Mercury is closer to the Sun than Venus is.

Mars had always seemed more promising. A century ago the famous American astronomer Percival Lowell argued that life, even intelligent life, existed on Mars. Mars has a 25° axial tilt so that the planet experiences seasons. Mars has ice caps, and as the Martian seasons change the polar ice caps grow and shrink. Polar ice caps suggest the presence of water, an essential ingredient for life. Lowell also thought that he saw colour changes throughout the Martian year. In summer he claimed to see dark green coloration that changed to brown in winter. To Lowell these colour changes suggested the existence of chlorophyll in plants. Most intriguing was Lowell's insistence that he saw many straight lines on the Martian surface that he interpreted as canals. With no visible oceans, we knew that Mars was a desert planet. Lowell thought that the canals were an attempt on the part of a Martian civilization to divert precious water resources, perhaps from annual ice cap melt, for agricultural uses.

While Lowell's ideas were on the extreme of those who held out hope for Martian life, many scientists thought that life there was quite possible. All of this changed in the second half of the twentieth century. We eventually found that Mars has a very thin atmosphere. Atmospheric pressure on Mars is less than 1% of that on Earth's surface (this pressure exists about 30 km above the Earth). The thin air does not hold heat, so the surface and air temperatures remain well below the freezing point of water even at the warmest locations. Nor does the Martian atmosphere offer much protection from dangerous solar radiation. Photographic reconnaissance from spacecraft beginning in 1965 revealed that large portions of the Martian surface have impact craters that suggest a lunar-type environment. There is not much doubt that any kind of life introduced on Mars today would have a difficult time coping with the environment. The only hope would be a few spots that are protected from the harsh conditions. Even there, life, if it could even survive, would not thrive. Despite these harsh conditions, today there appears to be a resurgence of interest in primitive life having once existed on Mars. For instance, the European Space Agency recently sent the Beagle 2 to Mars and NASA sent the Spirit and Opportunity rovers to Mars. A major justification for these missions was to search for evidence that life once existed on Mars.

One fact that should be appreciated about studying our nearest planetary neighbours is how fragile the conditions for life are. Venus is so similar to the Earth that it has been called 'Earth's twin.' The big difference between the two planets is their atmospheres. The Earth probably contains as much CO_2 as Venus does, so why isn't the Earth's atmosphere like Venus'? The answer is that nearly all of the Earth's CO_2 is locked into carbonate rocks. Some of the CO_2 in carbonate rocks is released into the atmosphere during volcanic eruptions, but several processes, including biological ones, remove the CO_2 and place it back into carbonate rocks. Liquid water, and particularly lower temperature liquid water, is essential in this process. Evolutionists believe that the atmospheres of the Earth and Venus started out pretty much the same 4.5 billion years ago, but then evolved in very different directions to produce the atmospheres that they now have. Many creationists believe that God probably created the two atmospheres in states close to what they are today. However, if the other planets suffered catastrophes in the recent past, this would not necessarily be true. Furthermore, we would probably agree with the evolutionists that even if we could magically and instantly transform the Venusian atmosphere into a terrestrial one, Venus' much closer distance from the Sun would likely prevent the transformed atmosphere from remaining so conducive for life. Venus' much higher temperature would probably send its atmosphere right back to the corrosive oven that it now is. Therefore, while Venus may have many other factors in its favour, its distance from the Sun is all wrong.

Mars suffers from the opposite problem. It is far enough from the Sun to be much cooler than the Earth, and, as previously mentioned, its thin atmosphere does not hold in heat (interestingly, the surface of the Earth is far warmer than it would be if its atmosphere did not hold heat). There are other problems for Mars. It is too small and has too little mass. The resulting low gravity prevents Mars from maintaining any significant atmosphere. Mars has a lower density than Earth, suggesting that it has a shortage of the heavier elements. Even if Mars had everything else right, its distance from the sun is probably too great to easily support life. However, mere distance from the Sun is not sufficient, because the Earth's moon has the proper solar distance, and yet it is dead. The Moon is far too small to have enough gravity to hold on to any atmosphere. Thus all of these worlds show the rarity of the Earth.

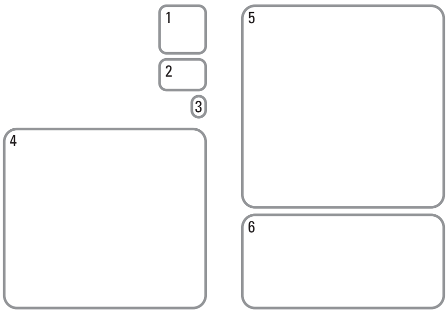
The space programme has allowed us to find another way that Mars and Venus speak of the creation model. In 1969 the Mariner 9 was the first spacecraft to orbit Mars. Its photographs revealed much of the Martian surface for the first time, including features that were obviously formed by flowing water. Though Mars is very dry today and liquid water cannot exist there now, it must have had abundant liquid water at one time. A few years ago the Sojourner rover sent photographs from the Martian surface that suggested that there once was a very deep layer of water on Mars. Some researchers went so far as to claim that Mars experienced a world-wide flood in the past. Of course, creationists think that the Earth had a world-wide flood at the time of Noah as recorded in the Bible. We also think that most of the Earth's sedimentary rocks were laid down during and immediately after the Flood. It is amazing that secular scientists refuse to believe the evidence that the Earth experienced a global flood, yet they willingly believe that such a thing was possible on Mars.

We cannot see the surface of Venus because its atmosphere has very thick clouds. However, we can use radar to penetrate the clouds. The United States has sent two spacecraft to Venus to do this. The most recent, the Magellan spacecraft a decade ago, used a radar altimeter to measure elevations of surface features and side aperture radar to determine surface texture. The mission provided us with a very detailed map of most of the Venusian surface. We have much evidence that plate tectonics has moulded the surface of Venus. This evidence consists of continent-like blocks, rift valleys, and mountain chains. Most scientists, including many creationists, believe that plate tectonics is the same force responsible for many of the Earth's surface features.

The surface of Venus has a number of widely-spaced impact craters. Surface features such as craters on a planet wear down over time. All the craters on Venus share a remarkable similarity in their condition, suggesting that all the craters have about the same age. This fact strongly suggests that the entire surface of Venus was recycled in a brief period of rapid plate tectonics, followed by little plate motion since. This inferred Venusian history contrasts with the supposed evolutionary Earth history in which the plates have slowly moved over the Earth's surface for eons. However, the history of Venus agrees very well with Earth history as understood by most creationists, who believe that the Earth's surface was completely reworked at the time of the Flood. For instance, six leading creation scientists proposed the catastrophic plate tectonics (CPT) model in 1994.

We do not know what catastrophes, if any, befell the other planets at the time of the Flood. However, it is very interesting that nearly all planetary scientists now agree that Mars once experienced a flood of Noachian proportions and that Venus also underwent catastrophic plate tectonics in the past. Despite these facts, most scientists reject out of hand the possibility that the Earth might have experienced such global upheaval. Creationists are encouraged by these discoveries on other planets, for they demonstrate that what we propose for Earth history is quite plausible.

Mars and Venus are more like the Earth than any of the other planets



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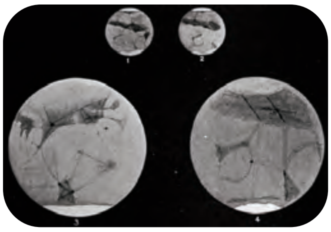

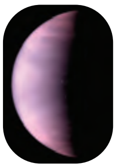

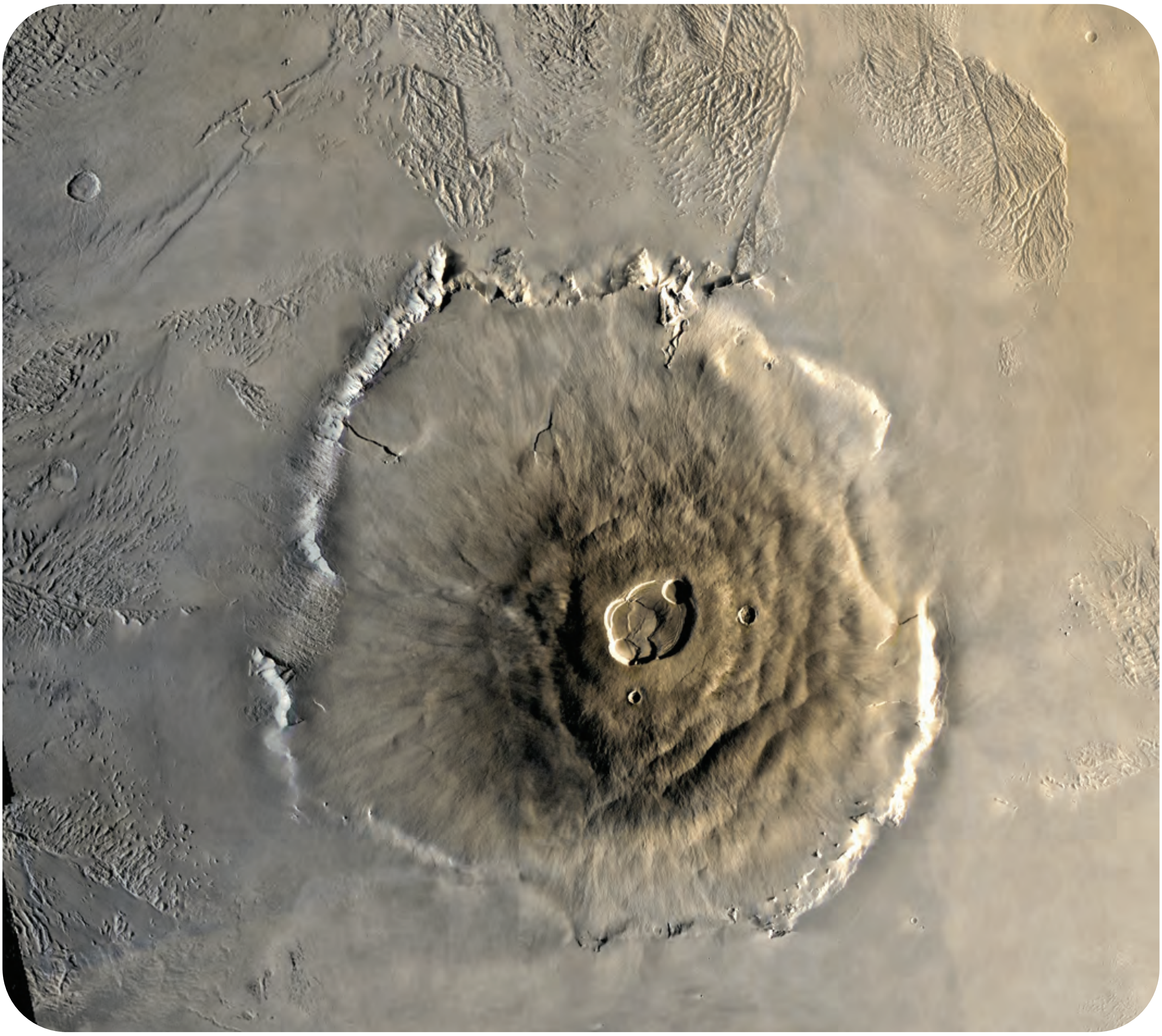

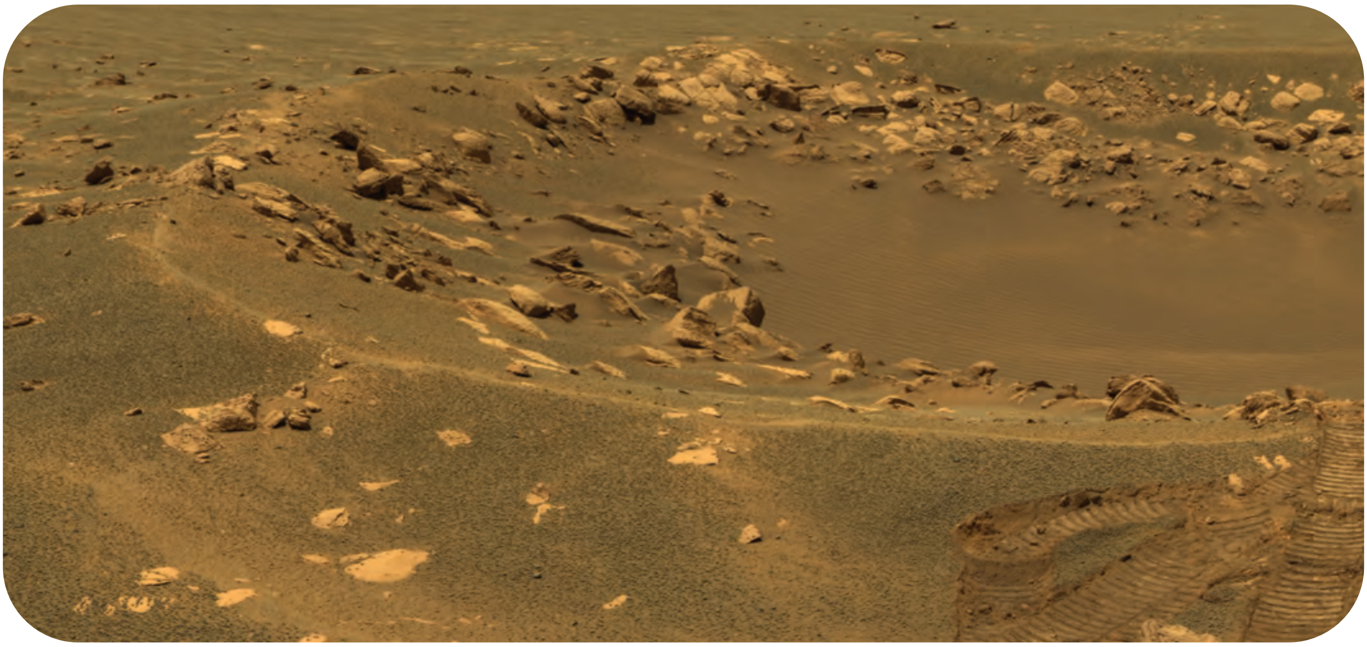

SUN, MOON, ECLIPSE... AND THE LORD

DAVID J. TYLER AND SHEENA TYLER

The final eclipse of the twentieth century is now history. It was everywhere hailed as an outstanding natural phenomenon. Over two billion people were said to have witnessed the event, from sunrise in Newfoundland to sunset in India. Does God speak through eclipses? If so, what is he saying?

Most of the reactions in the UK were along the lines of "Wow!", "How amazing!", "Superb!" Fringe groups gained media publicity with their 'spirituality' emphasis: the druids, astrologers and new agers. The voices of religious leaders were mute: the Pope was reported as seeing the partial eclipse in Italy, but he made no public comment. Further east, Islamic leaders were more forthright: the eclipse was a message from God. "This is a sign of doomsday and it should be a lesson to us all to stick to the word of the god" (from a Mosque in Jordan). In Iran, Muslims were directed to perform the 'namaz-e ayat', a prayer to celebrate God's glory said when experiencing an outstanding natural phenomenon. Still further east, thousands of Hindus took sacred baths, something thought to lead to reincarnation in the highest Hindu social caste, the Brahmin. Others recalled Hindu mythology, which interprets an eclipse as a combat between the demons Rahu and Keta, who eat the Sun in their wrath (*The Daily Telegraph*, 12th August 1999, p.23).

Should Christians have anything to say? How do we move on from saying "Wow!" to bring God's Word to our own lives and to the lives of others? We want to escape the snare of becoming 'secularised' in our thinking.

Genesis 1 informs us that the Sun, Moon and stars are signs that God uses, but we err if we think that these signs are analogous to messages saying, "God will do this, or that". Rather, they are signs of God's faithfulness in upholding his creation and his gracious provision on his creatures. There is no doubt that the Bible uses 'eclipse' imagery in prophecy. The opening of the sixth seal in Revelation 6:12f results in the Sun turning black. The Lord Jesus spoke of his coming, saying "the sun will be darkened" (Matthew 24.29 alluding to Isaiah 13:10). Should we conclude that an eclipse is always a sign of God visiting us in judgement?

Surely not, for a solar eclipse occurs somewhere on Earth in most years. It must be absurd to say that there is something special about a particular eclipse. Every day, when we are aware of the Sun, we can give thanks to God for his provision. We are dependent upon the Sun for warmth, for food, for all our physical needs. This dependency is so great that many people have resorted to Sun worship. The eclipse is a sign – that of God's purpose in making the Sun to shine. At His command, He can take it away. That would be a disaster for all – and this speaks of judgement. In an eclipse, we can only watch and we are powerless to affect change. Very quickly, we see the light fall and feel the temperature drop. When God comes in judgement, we can only be passive. We can observe, we can experience, we can stand in awe, but we cannot influence what He does.

There are particular reasons for thinking that the eclipse is a special kind of natural phenomenon, having special significance. This is because the Earth/Moon/Sun system is unique in our solar system. No other planet has eclipses in this way. The Sun is about 400 times larger than the Moon, and it is about 400 times further away from the Earth. So, from our vantage-point, the Moon fits almost exactly over the Sun. When the Sun's light is blotted out, the solar atmosphere, some planets and brighter stars may be seen. It is a rare and awesome sight! Naturalistic scientists say this is a chance arrangement. Writing in *The Sunday Times* (25th July 1999), Professor Richard Dawkins says, "The coincidence is pure luck, completely meaningless, though many prefer to credit providence". Our response is to say that because we believe in providence, we do not regard anything as "pure luck"! On the contrary, everything has meaning!

There are a host of extraordinary facets of our solar system. The more we know of our planet, the more we can see God's design. For instance, the amount and kind of the Sun's energy are just right. If the Sun's surface temperature was only 550°C (instead of the actual 5500 °C) and the Earth were nearer the Sun to get the same amount of heat energy, the climate would be very similar to what it is. But the very different radiation coming from the Sun would be quite inadequate for photosynthesis to occur and life would be impossible. Elsewhere in the solar system, the very massive Jupiter acts as a guard, helping to protect the Earth from collisions with comets and asteroids.[1]

What did the eclipse of 1999 mean to us? As a family, we were in Torquay on the 11th August to experience totality when the Moon completely covered the Sun. Thousands of other people were around us and we were all confident that the astronomers' predictions would be correct. We expected first contact to be just before 10 o'clock and that totality would begin at 11:14 am. No one expressed doubt that it would happen. In fact, you'd be considered crazy if you said the eclipse was unlikely to happen, either because you saw no evidence for it beforehand or because you felt it was foolish to put your faith in the predictions of astronomers.

It struck us how strong an analogy can be made with having an expectation of God's judgements, or even with believing in God. Our faith is firmly founded on a solid ground. God reveals himself in history, and supremely in Jesus Christ, His Son. Revelation is not primarily experiential; it belongs to a category called knowledge. That knowledge then is turned into experience as we work out our relationship of faith in the living God. And yet the skeptics refuse to receive this evidence, this knowledge.

Nonetheless, we must seek to win the many skeptics around us. We can tell them more about the glorious Creator of the wonderful universe; the Designer's signature is on all we see! We can demonstrate that the record of Scripture can be trusted and that Jesus really is the Son of God. We must not cease to warn people that this age will come to an end and that this whole Earth will be eclipsed in the Last Judgement of God. That will be a day when God's glory will be revealed and we will all stand in awe. The transient eclipses in our lifetimes are memorable reminders of what will surely come to pass. The Great Astronomer has already made the prediction.

NOTE

1. For more information on design issues and our planet, see 'Designer Earth' on the BCS web site. http://www.biblicalcreation.org.uk/design/bcs077.html.

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The more we know of our planet, the more we can see God's design

MAN ON THE MOON – A MYSTERY REVEALED

DAVID J. TYLER

For generations, people have gazed at the Moon and dreamed. Some have been bold enough to wonder whether man would ever get that far in his travels. They looked forward – but we look back. I can remember looking up at the Moon and thinking: "There are two men walking about up there at this very moment. What an extraordinary achievement!" It was hard to believe that it had happened, and today – 35 years on – it still seems somewhat unreal!

Three men went to the Moon: Commander Neil Armstrong, Buzz Aldrin and Mike Collins. Collins was left in the lunar orbiter while his colleagues descended in the lunar lander. "One small step for man, one giant leap for mankind" were the immortal words of Neil Armstrong as he got off the ladder and made the first footprint in moon dust. Aldrin soon followed down the ladder and both men got to work with their well-rehearsed programme of exploration, research and documentation. They collected samples, positioned scientific equipment and took photographs.

In 1994, the 25th anniversary of the event, a new insight was gained into this first lunar landing – something which few people knew or even suspected. The puzzle started when the astronauts returned to Earth. The film in their cameras was processed and examined. The press were asking for photos of Armstrong, because he was the first man on the Moon, but all that could be offered were pictures of Aldrin. What had happened? Aldrin's camera was okay – there were no technical faults.

The NASA official responsible for the still photography aspects of the lunar mission has told us what was going on behind the scenes. These are the official's words, as reported in The *Daily Mail* of 1st August 1994: "I was dumbfounded. I said to one of my colleagues, 'I don't see Armstrong'. He said 'You're crazy'." But there were no pictures of Armstrong! The NASA official continued: "There's a simple explanation. Aldrin was really mad at Armstrong for seizing the honour of being the first to walk on the Moon. Aldrin decided to get even with him. There was no way he was going to take Armstrong's picture". *The Daily Mail's* headline says it all: 'How envy "kept Armstrong out of Moon picture"'.

It is hard to find words to convey the significance of what happened. These two men had reached the climax of an extraordinary piece of history, involving unparalleled expenditure on research and development, years of dedicated effort and the construction of exquisitely sophisticated technology. The sheer brilliance, creativity and boldness of this achievement is testimony to the professional excellence of the large team of people behind it. Yet at this moment of culmination, Aldrin had an outburst of jealousy. Somehow, human experience failed to rise to the same heights as human technology.

The Bible casts light on this paradoxical situation: we are witnessing the problem of man's sinful nature. Our love of self often gets the better of us – Aldrin is no different from the rest of mankind. We should not condemn him, but seek to learn. His envy provides a powerful lesson for us. Despite all our human achievements, we cannot escape the corruption of our own hearts. Sin is always within us, even if we go to the Moon. The Earth's companion in space had never witnessed an act of sin, but as soon as man arrived in 1969, the signs of our rebellion against God were to be found.

Aldrin's desire to have what he wanted at the expense of another has many implications for us back home on Earth. He is a warning to all those who put their faith in technological progress – the Achilles Heel is not so much the technology but the human links in the chain. Wherever mankind goes and whatever mankind does is spoiled by sin. The human dream of a wonderful future through technological progress and human ingenuity and endeavour always seems to end up as a nightmare: we cause our own downfall. However hard we try, and whatever means we use, we fail to escape our slavery to sin. When we go to our grave, we take our sin and our guilt there too –and how then shall we face our Maker?

The Christian response to this impasse is to point to Jesus Christ – he alone can change our hearts, so that repentance, forgiveness and purity of motive become our daily experience. There is an interesting parallel to be found in C.S. Lewis's allegorical novel *Out of the Silent Planet*. The people who visited this planet for the first time thought it to be a paradise. However, these men brought their sinful hearts with them and were absorbed in thoughts of conquest and exploitation. They threatened to ruin what they found. The moral of the story is that man carries with him the seeds of his own destruction. What an inspiring contrast is the Christian hope for the future! God will bring about everything that is needed for the 'healing of the nations'.

It is no accident that Aldrin's jealousy came to the fore during the lunar mission. All things come to pass according to God's sovereign will. We are meant to learn from the incident. Without the transformation which Christ brings, there is no freedom from sin. Even when men go to the Moon, they take their sinful hearts with them!

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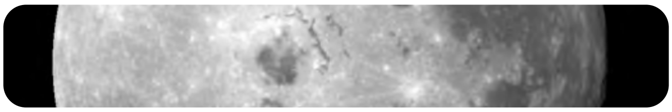
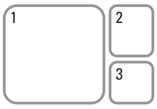
Moon data file



Average distance from the Earth	384,000 km (centre to centre)
Eccentricity of orbit	0.055
Maximum distance from the Sun	405,500 km
Minimum distance from the Sun	363,300 km
Inclination of orbit to ecliptic	5°9′
Average orbital velocity	1.022 km/s
Orbital period (sidereal)	27.321661 days
Orbital period (synodic)	29.5305882 days
Inclination of equator to orbit	6°41′
Equatorial diameter	3,476 km
Mass	7.35 x 10^{22} kg
Average density	3.36 g/cm^3
Surface gravity	0.167 Earth gravity
Escape velocity	2.38 km/s
Surface temperature	-170°C to 130°C (-274°F to 266°F)
Average albedo	0.07

Seeds, M.A. (2001). Astronomy: The Solar System and Beyond. *Second Edition. Brooks/Cole, Pacific Grove, California.*



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THE RINGED GIANTS – JUPITER AND SATURN

WAYNE R. SPENCER

If one were touring our solar system travelling outward from Earth, after passing the orbit of Mars there would be a large region about 554 million kilometres (or 340 million miles) across where there are no planets. Then Jupiter would be encountered at 5.2 Astronomical Units distance from the Sun (1 A.U. is approximately 150 million kilometres or 93 million miles). Saturn lies nearly twice the distance from the Sun as Jupiter. Jupiter and Saturn inspire much wonder, Jupiter for its size and Saturn for its beautiful rings. Saturn has very extensive rings which are easily observed from Earth. But Jupiter also has rings, though they are hard to see, being made up of microscopic dust. Both Jupiter and Saturn rotate very rapidly and would have a 'day' of roughly 10 hours. Jupiter is much more massive than all the other planets in our solar system, about 318 times the mass of Earth. Saturn, which is the next largest planet, is about 95 times the mass of Earth. This makes Jupiter's mass more than double the combined mass of all the other planets. Yet, even this is only about one thousandth of the mass of our Sun. Because its mass is so great, Jupiter has a large effect on the motions of some other objects in the solar system. Jupiter and Saturn are often called 'gas giants', though calling them 'fluid planets' would be a more accurate description. Liquids and gases are both considered fluids in science. Jupiter and Saturn are made up of both gases and liquids. Jupiter and Saturn's outer layers are gas, but at the high pressures that exist deeper inside, the gases condense to liquids. This means Jupiter and Saturn do not really have a solid surface, though deep in their centres there may be a solid core. They are both made up of over 80% hydrogen gas, with helium the next most abundant element. There are also small amounts of methane, ethane, and ammonia. Naturalistic origins theories for the formation of large gaseous planets have been based to a large degree on Jupiter and Saturn. From a creation perspective, these planets, which are giants compared to Earth, show the greatness and creativity of the Creator-God. Today large gaseous planets are believed to exist orbiting other stars. These planets are often compared to Jupiter and Saturn by planetary scientists. Usually these extrasolar planets have orbits very different from Jupiter and Saturn in our solar system.

Earth is found within what is called the 'inner solar system', generally considered to be from Mars inward toward the Sun. Earth's orbit defines a plane called the ecliptic, which is used to measure how inclined orbits are in the entire solar system. All the planets, with the exception of Pluto, have orbits close to this plane in inclination. All the planets in the inner solar system are rocky planets, though Venus, Mars, and Earth have gaseous atmospheres. But in the outer solar system we find there are four large gaseous planets, Jupiter, Saturn, Uranus, and Neptune. Then there is Pluto, which seems like a kind of 'misfit' in that its orbit is more elliptical than the other planets, and is also more inclined. There is debate today over whether to consider Pluto a true planet or not.

There are many small objects in the solar system and small bodies such as the asteroids and comets are very influenced by the gravity of Jupiter and Saturn. Between Mars and Jupiter the large 'gap' without a planet is generally known as 'the asteroid belt'. Asteroids are not always confined to just this region, however. There has been a significant effort in recent years to search for asteroids that come close to Earth's orbit. Objects that come near Earth's orbit are called Near Earth Objects, or NEO's. Some asteroids are found at a distance from the Sun that makes them very influenced by Jupiter's gravitational pull. One group of asteroids, known as the Trojans, actually share Jupiter's orbit. There are also clearly 'gaps' in the asteroid belt where Jupiter has pulled objects away from certain positions. There are also a few unusual small objects that have orbits taking them beyond Jupiter and even beyond Saturn. In 1977 an object called Chiron was discovered in an orbit between Saturn and Uranus. The region near Neptune is now often called the transneptunian region. Also, we now know there are a number of objects located beyond Neptune. There has been much interest in these objects among astronomers in recent years. These objects have come to be known as Kuiper Belt Objects, or KBO's. Some believe that short period comets (that require less than 200 years for one orbit around the Sun) originate from the Kuiper Belt region beyond Neptune. Comets are also very influenced by Jupiter and Saturn. In 1994 the Shoemaker-Levy comet (SL-9) was photographed colliding with Jupiter. The SL-9 comet had orbited the Sun but it passed close enough to Jupiter at some point to allow Jupiter to capture it. This capture took place approximately two years prior to when the collisions occurred. When the comet got close enough to Jupiter, the gravitational tidal forces pulled it apart. Later, a number of impacts with Jupiter were seen in July 1994 over a period of about one week. Though comets had been observed disrupting into fragments before, the case of SL-9 was the first opportunity on record to observe an actual collision of those fragments with a planet. Some comets have their orbits drastically altered by Jupiter, or they may be captured by it, but they do not break up as Shoemaker-Levy did. This is a general picture of the outer solar system and how Jupiter and Saturn influence the solar system.

Jupiter

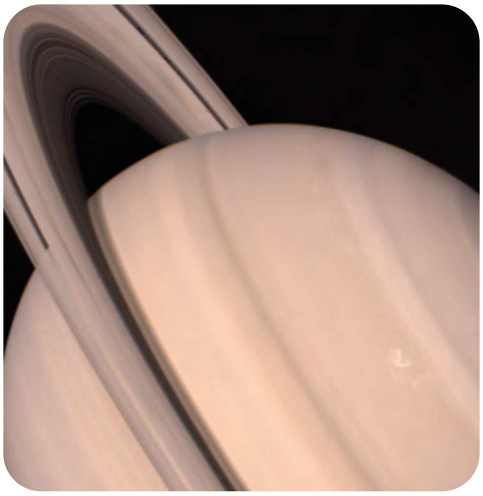
Jupiter and Saturn have more moons than any of the other planets in our solar system and a number of moons have been discovered in recent years. In the year 2003 alone, 21 new moons were discovered orbiting Jupiter. New telescope technology has made it possible to detect fainter objects than ever before. Jupiter is now known to have 61 natural satellites (Saturn has 31). The majority of these are smaller than 200 km diameter, in fact, the newly discovered moons at Jupiter are all probably smaller than 5 km in diameter. This is based on estimates of their sizes, not precise figures. For Jupiter, 36 of its 61 moons travel retrograde around Jupiter, opposite to the direction Jupiter spins. Seven of Saturn's moons travel retrograde. The retrograde moons are usually found to be grouped near each other. This strongly suggests there was one object that was broken apart in a collision some time in the past. But the eccentricities of the orbits of these new moons do not suggest they were captured like SL-9, unless some force dramatically altered their orbits since their capture. Present processes cannot explain how there could be enough collisions or captures to produce so many objects as we now find among Jupiter's moons. This may imply a catastrophic event or process in the past to explain moons and craters. Planetary scientists have suggested that in the early history of the solar system (over 4 billion years ago in their view) comets were captured by Jupiter with much higher frequency. In the evolutionary view of the solar system, moons are generally believed to form as the planet forms, by the dust and other particles pulling together from the nebula that the whole solar system came from. But there are difficulties with this concept for the formation of some moons.

For Jupiter, the well known satellites are Io, Europa, Ganymede, and Callisto, which are referred to as the Galilean moons, after Galileo who discovered them. These moons are comparable to our Moon in size, though Ganymede and Callisto are larger. Each of these moons has interesting unique characteristics. The Galilean moons of Jupiter are easy to observe with even a very small telescope. Planetary scientists have encountered very challenging mysteries for each of them. For Io, it is the high heat output and active volcanoes. With Europa, it is the nature of the interior and whether there is liquid water under the surface. For Ganymede, it is the variety of geological structures on its surface. For Callisto, one mystery is the unusual form of the rings around the Valhalla impact basin. This is one of the largest impact sites in the outer solar system, with concentric ridges forming a structure nearly 3,000 km in diameter. Yet, in several respects it does not have a shape or proportions like other large craters.

Scientists have attempted to explain how natural processes alone would be sufficient to explain how large gaseous planets might form from a nebula in space. The theory has it that the nebula would collapse by gravity into a spinning disk of dust, gas, ice, and mineral grains. The microscopic solid particles would collide and stick together, forming larger and larger macroscopic objects. Then these objects, called planetesimals, would pull more and more material onto them by gravity. It is believed that if a solid core 10 Earth masses in size formed in this way, this would be enough to pull large amounts of the gas in the disk onto the solid core, thus forming a gaseous planet. The bigger the solid core became before the disk could dissipate and become too thin, the bigger the gas planet would be in the end. As this process takes place there are other processes occurring in the Sun that at one point would drive large amounts of gas out of the solar system. This puts a time limit on the formation of the solid planet core. For Saturn, planet formation models imply there would not be enough time for the core to get large enough before the gases dissipate. Thus, Saturn by the naturalistic evolutionary approach, would not be as large as it is found today. The same problem could affect Jupiter.

Jupiter is a powerhouse of energy in the solar system. Though it is very large, it spins on its axis very rapidly. It also has a very powerful magnetic field and gives off one million million Watts of energy in the form of radio waves! Considering the radio waves and heat given off by Jupiter, it gives 1.67 times the energy that it receives from the Sun. In December of 1995 the Galileo spacecraft sent a probe into Jupiter to collect data on its gases. It found several things surprising to planetary scientists. Temperatures and wind speeds were higher than expected, which suggests there is heat coming from the interior somehow. This type of energy and heat issue may be easier to explain assuming Jupiter is young rather than billions of years in age (Samec, 2000, pp.3-4). There were other surprises in the composition of the gases in Jupiter from the Galileo spacecraft. There was no evidence of water clouds in Jupiter's upper atmosphere, which had been expected after the SL-9 comet impact (Beebe, 1997, p.226). There continues to be research efforts to explain the data from the Galileo probe. There continue to be ongoing unanswered questions even today as scientists try to reconcile all the data.

Jupiter and Saturn have now been observed over a significant period of years by various research efforts. Their various bands of clouds and occasional storms have been studied a great deal. Jupiter and Saturn both change their appearance over time. A very visible feature on Jupiter is the 'Great Red Spot'. This spot has been observed to exist for at least 150 years. It is essentially a giant hurricane. The Red Spot is located between two streams of gas that move in opposite directions (Beebe, 1997, pp.33, 35). South of it there are mild winds moving eastward; this is the same direction as the motion due to the spin of the planet. North of the Red Spot there are very strong westward winds. If Jupiter were highly tilted the different amounts of solar radiation falling on Jupiter's Northern and Southern hemispheres could explain this. But because Jupiter is only tilted 3 degrees, the reason for the dramatic contrast between the North and South equatorial winds is a mystery. The Red Spot also varies in its position along Jupiter's longitude (Beebe, 1997, p.36). From about 1930 to 1982 the Red Spot drifted over 270 degrees eastward in longitude, which is about 3/4 of the way around the planet! The size of the Red Spot has varied as well, but the size change is only in the horizontal dimension. The vertical dimension of the spot has stayed nearly constant for years. The reasons for these changes in the Red Spot are not known. The spot also speeds up and slows down



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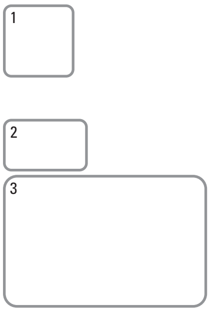

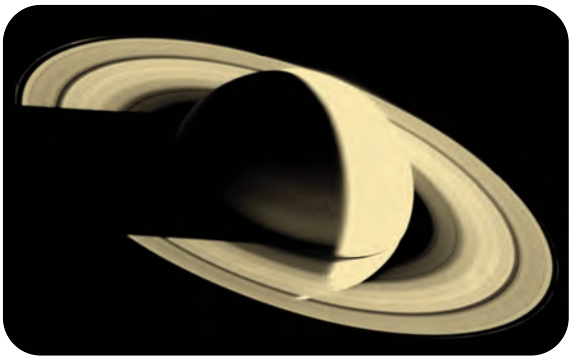

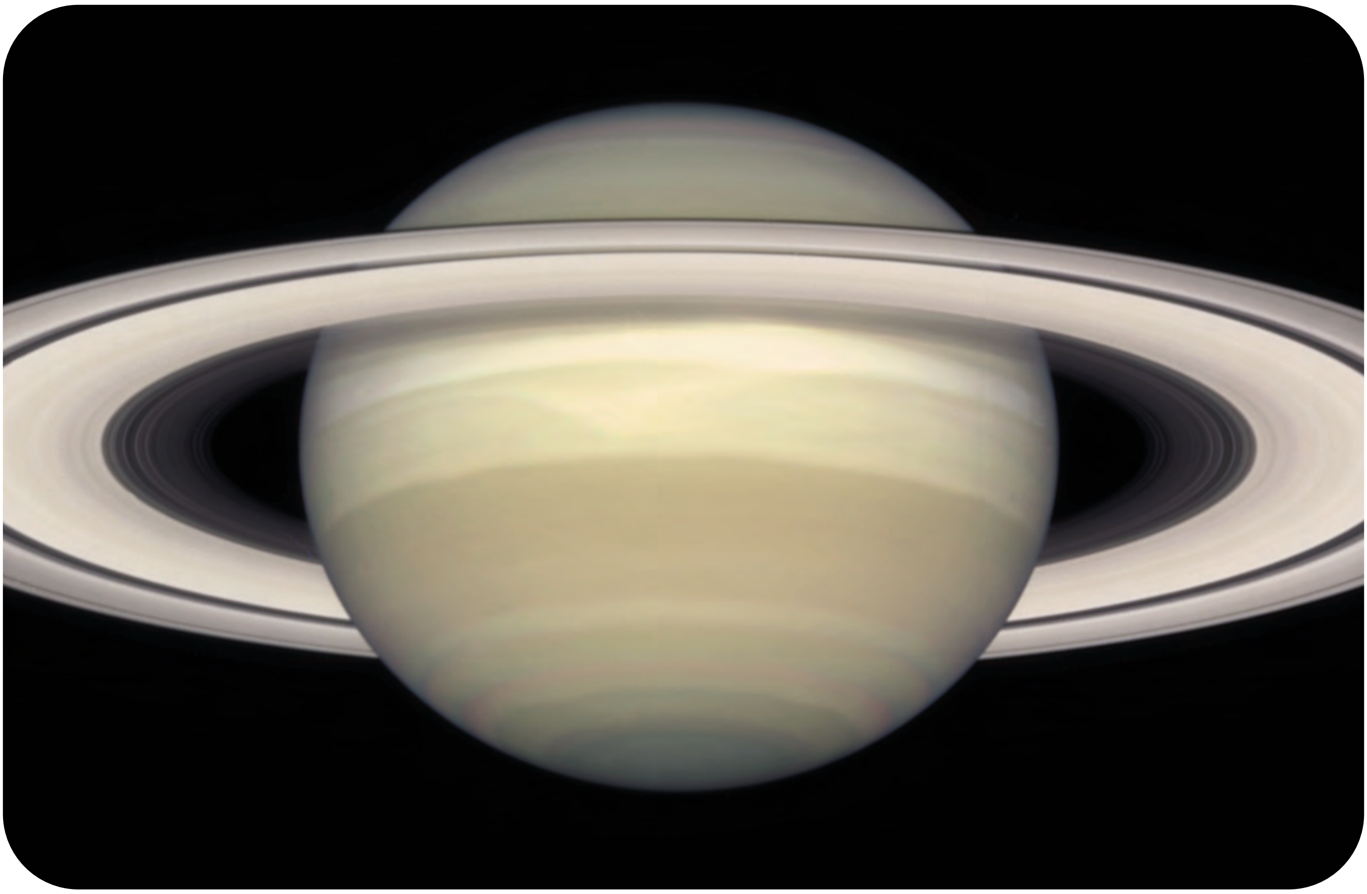

over periods of days to weeks, relative to the spin of the planet. Much is still not understood about Jupiter's Great Red Spot.

Saturn

In June 2004 the Cassini spacecraft will enter orbit around Saturn. The Cassini spacecraft will remain in orbit around Saturn for some years, similar to how the Galileo spacecraft has done for Jupiter. Cassini will collect much new information about the rings of Saturn, Saturn's moons, and the planet itself. Of special interest is that Cassini is equipped with a probe that will detach from Cassini and descend into the atmosphere of Saturn's moon Titan. Titan is unique in the solar system as having an atmosphere that is more dense even than Earth's. This probe is known as Huygens and was built by the European Space Agency. The Huygens probe has been designed to function even if it lands in liquid methane, which may exist on Titan's surface. Cassini was launched in 1997. Cassini made two flybys of Venus, one flyby of Earth, and another flyby of Jupiter, all to pick up speed to make the trip to Saturn.

Saturn has been called the most beautiful planet in the solar system, mainly because of its extensive system of rings. Saturn is nearly double the distance from the Sun as Jupiter and has the lowest density of all the planets, being about 70% of the density of water. Saturn is tilted more than Jupiter (27 degrees) and this makes the appearance of the rings vary dramatically over periods of several years. Saturn requires about 29.5 Earth years to complete one revolution around the Sun; Jupiter requires nearly 12 Earth years to do the same. Saturn's colour is a yellow with some white cloud features. Jupiter's colour is more reddish to brown. It is not really known for certain what makes this difference in colour, because the composition of Saturn is very much like Jupiter. Saturn is made up mostly of hydrogen and helium, though the proportion of helium seems to be less than that for Jupiter. Saturn has very strong eastward winds in a wide belt around its equator. These winds have been clocked at speeds of about 1440 kilometres per hour (900 miles per hour) or more. This is much faster than any winds on Jupiter. There are also occasionally some large storm systems in the equatorial region that last for periods of months. In December 1994 one of these storms, about the size of Earth, was observed by the Hubble Space Telescope. The rapid winds on Saturn make the rotation period (a Saturnian 'day') at the equator about 25 minutes less than it is near Saturn's poles. At the poles Saturn's 'day' would be about 10 hours 39 minutes. Saturn also possesses a strong magnetic field, though not nearly as intense as that of Jupiter. The strong winds as well as the average temperature of Saturn imply an internal energy source of some kind. In fact, Saturn gives off three times the amount of energy it receives from the Sun (Baugher, 1988, p.207).

Then there are the rings. Saturn's rings are beautiful and complex. Saturn has much more material in its rings than all the other rings of Jupiter, Uranus, and Neptune. Saturn's rings are over 60,000 kilometres wide; in recent studies of the rings, scientists have estimated the vertical thickness of the rings is something between 10 and 100 metres. The rings are made up of many chunks of water ice, though it is possible some of them could have rock inside. There may be small amounts of organic compounds in this ice in the ring objects (Poulet and Cuzzi, 2002, p.350). The ring objects have been estimated to have sizes ranging from 1 cm to 20 metres (Nicholson *et al*, 2000, p.499). Even with the Voyager photographs and the Hubble Space Telescope, it has not been possible so far to distinguish individual ring objects in any photograph. So, the above information on the thickness of the rings and the sizes of ring particles should be considered tentative estimates. Saturn's rings are very dynamic, with some features that have been observed to change over periods of just minutes or a few hours.

The Voyager spacecrafts made amazing discoveries about Saturn's rings. There were what looked like spokes in the rings. There was also a ring that was made up of two 'strands' with one braided around the other. The Voyager spacecraft also showed that the closer you looked, the more rings you could see. Planetary scientists have described them as 'rings within rings within rings'. Some rings had surprisingly sharply defined edges though scientists had expected them to essentially fade out gradually, assuming they were very old. The moons pull material in the rings in such a way that they could create a few of the gaps in the rings. There are also certain waves that travel through the rings due to collisions of the objects that probably produce some of the structure in the rings. But, it is not clear whether all these natural phenomena are adequate explanations of the intricate structure in Saturn's rings. It is estimated the total number of separate rings may be in the hundreds of thousands.

The origin of Saturn's rings continues to be debated. The two theories supported most by the scientific community today are 1) that there was a moon near Saturn that was broken apart either by tidal forces or by an impact, or 2) that the ring objects accreted from dust and ice particles at the time Saturn formed, but could not form into larger objects like moons. Since the Voyager mission there has been growing support for the first of these two approaches. As a result, some planetary scientists today hold that Saturn's rings are actually much younger than the planet, about 50 to 100 million years from an evolutionary perspective (McNab and Younger, 1999, p.124). Young-age creationists have also argued Saturn's rings must be young, not only because of the intricate structure and sharp edges but also because the rings are losing water as water falls onto the planet (Snelling, 1997). 'Tidal forces' refers to an effect due to gravity in a case where the force of gravity differs across distance enough to pull an object into a nonspherical shape or maybe even pull it apart. The gravitation force or tidal force from Earth's Moon pulls Earth into a slightly nonspherical shape so that Earth's diameter is greater at the equator than it is at the poles. For small objects near a planet, the tidal forces can pull the object apart in some cases. However, tidal disruption would probably not create a large number of fragments. So, tidal disruption of a former moon of Saturn into possibly millions or billions of ring objects may not be plausible in a young solar system because it probably would not generate enough objects. However, if a large collision broke up a moon only a few thousand years ago, this would generate many more objects but Saturn's rings may not be so uniform as they are today, with most of the objects following circular orbits. The optical properties and brightness of the rings does not vary significantly as Saturn rotates (except for in the 'spokes'). There are ring objects that are in elliptical orbits and there are a few nonuniform rings at Saturn, but these are exceptions to the general rule. If a moon or moons were disrupted in the past, the fragments would tend to make the rings more and more uniform over time, due to collisions making the speeds of the objects more nearly the same. Thus, even from a creation perspective, the question of the origin of the rings is a challenging one. They could have some catastrophic origin or they could have been created with the planet. But there are multiple lines of evidence from the rings of Saturn that they cannot be billions of years in age.

Thousands of years ago the God of the Bible created two extraordinary planets in our solar system, Jupiter and Saturn. Jupiter and Saturn are both very bright in the night sky and are exciting to see even with a small telescope. These two planets serve an important purpose of protecting Earth from many impacts from comets. Because these two planets are so massive, comets are much more likely to impact with Jupiter or Saturn, than to collide with any object in the inner solar system. This tends to prevent some impacts with Earth that could threaten life. The size, beauty, and unique properties of these planets also show us the creativity and power of God, since He made them. We have so much factual data about these planets and the upcoming Cassini mission will undoubtedly bring new surprises and raise new questions about Saturn. Though we have learned much, even some very 'basic' questions cannot be answered today with any confidence, such as 'Why are Saturn and Jupiter such different colours when their compositions are so nearly the same?' With continued research and God's help, we can look forward to seeing how a creation perspective helps answer many questions about our solar system.

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Thousands of years ago the God of the Bible created two extraordinary planets in our solar system, Jupiter and Saturn

Jupiter data file

Average distance from the Sun	5.2028 A.U. (7.783 x 10^8 km)
Eccentricity of orbit	0.0484
Maximum distance from the Sun	5.455 A.U. (8.160 x 10^8 km)
Minimum distance from the Sun	4.951 A.U. (7.406 x 10^8 km)
Inclination of orbit to ecliptic	1º18'29"
Average orbital velocity	13.06 km/s
Orbital period	11.867 y (4334.3 days)
Period of rotation	9h 55m 30s
Inclination of equator to orbit	3º5'
Equatorial diameter	142,900 km
Mass	1.899 x 10^{27} kg
Average density	1.34 g/cm^3
Gravity at base of clouds	2.54 Earth gravities
Escape velocity	61 km/s
Temperature at cloud tops	-130ºC (-200ºF)
Albedo	0.51
Oblateness	0.0637

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Saturn data file

Average distance from the Sun	9.5388 A.U. (14.27 x 10^8 km)
Eccentricity of orbit	0.0560
Maximum distance from the Sun	10.07 A.U. (15.07 x 10^8 km)
Minimum distance from the Sun	9.005 A.U. (13.47 x 10^8 km)
Inclination of orbit to ecliptic	2º29'17"
Average orbital velocity	9.64 km/s
Orbital period	29.461 y (10,760 days)
Period of rotation	10h 39m 25s
Inclination of equator to orbit	26º24'
Equatorial diameter	129,660 km
Mass	5.69 x 10^{26} kg
Average density	0.69 g/cm^3
Gravity at base of clouds	1.16 Earth gravities
Escape velocity	35.6 km/s
Temperature at cloud tops	-180ºC (-292ºF)
Albedo	0.61
Oblateness	0.102

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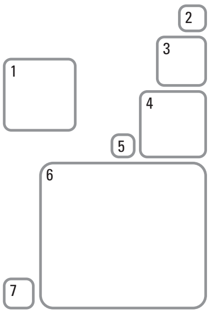

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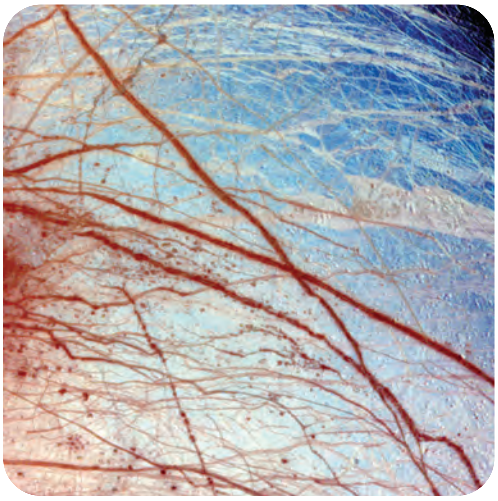
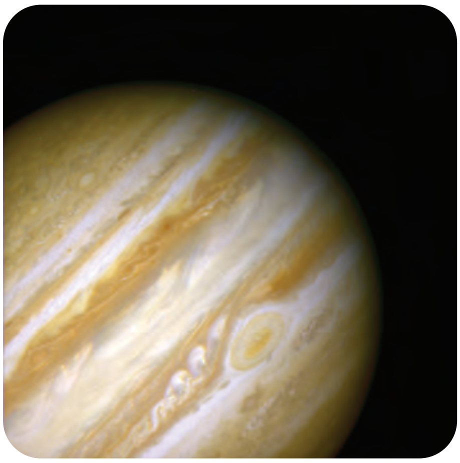




THE OUTER LIMITS – URANUS AND NEPTUNE

PAUL GARNER

Introduction

The outer planets are strikingly different from our own rocky world. Uranus and Neptune are giants with deep atmospheres of hydrogen, helium, and methane. They are enigmatic planets – no surface features are visible through Earth-bound telescopes – and since their discovery they have posed many puzzles for planetary observers. Although the Voyager missions have helped to answer some of our questions, they have raised many others. This article will review what we know about these strange planets. We will also consider the question of how they originated – did they form by natural processes or were they specially created by God?

Origin of Uranus and Neptune

The evolutionary view is that Uranus and Neptune formed about 4.6 billion years ago by the collision of millions of icy particles – called planetesimals – in a diffuse nebula surrounding the early Sun. Until recently, computer simulations were unable to explain how the two worlds could form so far from the Sun. According to the theory, the further a planet is from the centre of the nebula the longer it must have taken to form. Attempts to simulate the origin of the outer planets by colliding particles had suggested that bodies the size of Uranus and Neptune would require about 10^{10} years to form by the accretion of colliding particles (Dormand and Woolfson, 1989, p.39) – twice the supposed age of the solar system! One astronomer commented:

> *"What is clear is that simple banging together of planetesimals to construct planets takes too long in this remote outer part of the solar system. The time needed exceeds the age of the solar system. We see Uranus and Neptune, but the modest requirement that these planets exist has not been met by this model." (Taylor, 1998, p.73).*

To solve this problem, it has been suggested that Uranus and Neptune formed closer to the Sun, where planet-formation time scales would have been shorter, and then migrated outwards to the place where we find them today (Thommes *et al*, 1999). Calculations show that a planet embedded in a disk of planetesimals could be 'lifted' into a higher orbit by energy and momentum exchange with the planetesimals (Hahn and Malhotra, 1999). Furthermore, recent computer simulations now suggest that giant planets like Uranus and Neptune may be able to form from a primordial disk of planetesimals in an astonishingly short time – about 1,000 years (Mayer *et al*, 2002). Of course, the existence of a thick primordial disk of planetesimals has never been unequivocally established. Simulations like these are only as good as the assumptions made by the investigators. Relatively little is known about Uranus and Neptune – let alone the conditions in the hypothesised primordial disk – so a great variety of possibilities can be considered. Even if further research makes it possible to construct a plausible evolutionary scenario, we cannot conclude that it must have happened that way.

The bland face of Uranus

Uranus is perhaps the most mysterious of all the planets. It was discovered by William Herschel in 1781 – and the discovery made him famous. It led to his appointment as Court Astronomer to King George III of England and Hanover. It is not surprising that Uranus took so long to be discovered because, although it is four times the diameter of Earth, it is so far away that it is only just visible to the naked eye. It is a bland world with a blue-green tinge but no obvious surface features. Even computer enhancement of the images taken by Voyager 2 during its 1986 fly-by revealed little more than a few faint clouds near the equator. The density of Uranus is between that of the Earth and Jupiter, suggesting that it is composed of something less dense than rock but more substantial than gas. Scientists have concluded that it consists largely of water with dissolved ammonia and methane. Distinct boundaries are thought to be lacking in the interior of Uranus: a small rocky core grades into a deep liquid ocean which thins out into a diffuse atmosphere.

Rings and moons

In 1977 it was found that Uranus has a system of thin rings. This was a chance discovery made by astronomers watching an occultation – i.e. the disappearance of a star behind the planet. Before and after the occultation, the star blinked on and off as if its light was being temporarily obscured. Astronomers realised this was caused by a system of rings surrounding the planet. Photographs taken by Voyager 2 revealed ten narrow rings and one broader ring. They are very dark, unlike the rings of Saturn, and there are two possible reasons for this: (1) they are made of rocky – not icy – particles; (2) they have become darkened by exposure to radiation from space. The rings seem to be made up of particles several metres across.

Five moons of Uranus – Miranda, Ariel, Umbriel, Titania, and Oberon – were known before the Voyager mission (see **TABLE 1**, p39). Voyager 2 found ten more satellites, all closer to Uranus than Miranda. The names of the new moons were taken from the works of Shakespeare: Cordelia, Ophelia, Bianca, Cressida, Desdemona, Juliet, Portia, Rosalind, Belinda, and Puck. These small moons are being subjected to an incessant bombardment of cometary material that chips pieces off them. This is probably the source of the material that makes up the rings. The rings must be continually supplied with new material because the particles interact with Uranus' thick atmosphere and rapidly spiral towards the planet. These particles were photographed by Voyager 2 after it had flown past the planet – the images show a broad swathe of dusty bands backlit by the Sun.

Some of these small moons may be fragments of a much larger moon that was blasted apart by a violent impact. This may explain the strange features of Miranda. Planetary scientists expect most small moons to be dead, cratered worlds – but Miranda has a perplexing landscape. There are three large rectangular or oval areas up to 300 kilometres across. One of them is a peculiar 'chevron' with high ridges and sharp edges. Some have suggested that there was once a massive collision which ripped Miranda apart – and that some of the pieces reassembled to form this freakish landscape. Others insist that Miranda must always have been a single body and that the strange markings are the result of 'hot spots' of warmer ice rising from inside the moon. There is clearly much we do not yet understand about how Miranda's surface features were formed.

The planet that rolls on its side

Curiously, Uranus is spinning on its side – its equator is tilted to its orbit by 98°. This means that the poles of Uranus point alternately at the Sun as the planet completes its 84-year orbit. As a result, Uranus has very unusual seasons that last for years. Evolutionary scientists have difficulty accounting for the strange spin of this world. According to the currently accepted evolutionary model for the origin of the solar system, Uranus must have started off rotating upright like the other planets. Therefore, it has been suggested that Uranus was knocked over when another large body struck the planet near one of its poles. If this really happened, it is hard to understand why the orbit of Uranus is so circular – a massive impact ought to have disturbed it (Steidl, 1983, p.99). Furthermore, the moons of Uranus are in highly circular orbits around the planet's equator. How did the moons escape being scattered into random orbits or lost from the system altogether (Steidl, 1983, p.99)? Astronomer Patrick Moore, well known for his *Sky At Night* TV programme, says of the giant impact theory: "This does not sound very plausible, but it is not easy to think of anything better." (Moore, 1991, p.88). Creationists can consider the possibility that Uranus was created spinning on its side as we see it today.

The weather patterns on Uranus are also unusual. The strange tilt of Uranus means that at times the north pole of the planet points towards the Sun (the 'northern summer'), and sometimes the south pole points towards the Sun (the 'southern summer'). During the 'spring' and 'autumn' seasons Uranus is side-on to the Sun – with most of the sunlight falling on the equatorial regions. Each of these four seasons is about twenty years long! Because the Sun's heat is currently falling on one pole it was thought that the winds on Uranus might blow in a north-south direction. In fact, the winds blow east-west, parallel to the equator, as with the other planets. It seems that the rapid rotation of Uranus has more of an effect on the atmospheric circulation than the Sun's heat – which is weak so far out in the solar system. Another surprising observation is that the pole of Uranus that faces away from the Sun is just as warm as the one facing it. There must be some way that heat is effectively transferred from one pole to the other, but astronomers are not sure what it is.

The magnetism of Uranus – evidence of young age

Voyager 2 also made some surprising discoveries concerning the magnetic field of Uranus. Those who accept that Uranus is 4.6 billion years old had predicted that it would have a very small magnetic field, or none at all (Dessler, 1986). By contrast, a young-universe theory of planetary magnetism had predicted that Uranus would have a magnetic dipole moment between 2 x 10^{24} ampere-metres^2 to 6 x 10^{24} ampere-metres^2 (Humphreys, 1984). The actual measured value was 3 x 10^{24} ampere-metres^2, well within the bounds of the creationist prediction (Humphreys, 1986). Furthermore, Uranus' magnetism is generated halfway out from the planet's core and is at an angle of 60° to its axis of rotation. Scientists had expected the field to be generated near the core and to line up approximately with the rotational axis – as is the case with the magnetic fields of Earth, Jupiter, and Saturn. Planetary magnetic fields are caused by the motion of currents in an electrically-conducting fluid. However, the centre of Uranus is thought to consist of rock that does not conduct electricity – and this is why the field is offset from the core. It is thought to be generated in the lower parts of the deep liquid ocean of Uranus. The asymmetry of the currents in this ocean may explain why the field is tilted at such a strange angle.

No heat source on Uranus

Uranus is also peculiar in other ways. Unlike the other giant gas planets, Uranus does not seem to radiate heat (Henry, 2001). In many respects, Uranus and Neptune are 'twins' – but Neptune possesses a strong heat source while Uranus does not. Some theorists have tried to explain this by appealing to internal mixing caused by giant impacts. They have suggested that Neptune suffered a collision that stirred its interior and caused heat to leak to its surface. On the other hand, they suggest that Uranus was struck very obliquely, causing it to rotate on its side. This impact failed to stir up Uranus' interior so most of its heat is still trapped there. However, this mixing theory is now doubted by many scientists. Voyager 2 found that Neptune rotates on its axis every 16 hours – a period too small for the mixing to have taken place. The differences between the gas planets are still not understood and debate continues about these matters. The internal sources of heat in Jupiter, Saturn, and Neptune are usually attributed to gravitational shrinkage. If this is the case, it is something of a mystery as to why Uranus is different in this respect. Perhaps the thermal characteristics of these planets result from their special creation.

Neptune – strange weather and strong winds

Neptune is about the same size as Uranus and also consists of a rocky core, a deep watery ocean, and a thick atmosphere of hydrogen, helium, and a small amount of methane. It was only discovered in 1846 after mathematicians realised that another planet was exerting a gravitational influence on Uranus. This allowed astronomers at the Berlin Observatory to pinpoint Neptune's location in the sky. A few facts were soon established about this mysterious world, such as how big it was and that it had at least two moons but, until the Voyager missions, not much else was known about it.

In 1989, Voyager 2 made a close pass, revealing a beautiful blue world with wispy white clouds. The blue colour is caused by the methane in Neptune's atmosphere – the gas absorbs red light and reflects blue wavelengths. By contrast with the blandness of Uranus, there are interesting surface features on Neptune. The most prominent feature is the Great Dark Spot, a huge 'storm' about half the size of the Earth. Near the south pole is another smaller dark spot. Between the two is a fast-moving white spot, which became known as 'The Scooter'. Actually this bright cloud stays in approximately the same place relative to the deeper regions of Neptune – but the two dark spots are moving in the opposite direction to the planet's rotation.

The atmosphere of Neptune is about the same temperature as that of Uranus, though it is further from the Sun. It is thought that the internal heat of Neptune warms the outer layers of the planet. Neptune has the fastest winds of any world in our solar system – ten times faster than an Earth-bound hurricane! What drives these winds is, however, a great puzzle. The sum of the heat that Neptune receives from the Sun, plus its own internal heat, is not adequate to generate such powerful winds. There must be processes on Neptune that do not operate on Earth.

More mystifying magnetism

On 25th August 1989, Voyager 2 made the first measurements of Neptune's magnetic field. The field turned out to be quite strong but less intense than those of the other giant planets. As with Uranus, the measurements were in line with the predictions derived earlier by Humphreys' young-age theory. Humphreys (1984) had predicted that Neptune would have a magnetic dipole moment of the order of 10^{24} ampere-metres^2. The actual measured value was 1.5×10^{24} ampere-metres^2 (Humphreys, 1990). As with Uranus, the magnetic field of Neptune is tilted with respect to its axis of rotation and offset from its centre. The magnetic field is carried along as Neptune rotates and this allowed Voyager 2 to determine the length of the Neptunian 'day' (sixteen hours and seven minutes). Like the other giant planets, Neptune spins much more rapidly than the Earth, even though it is so much larger.

Rings and arcs

Neptune also has a ring system – but it is very thin and difficult to see. It contains only one-thousandth as much matter as the rings around Uranus. The long-exposure cameras on Voyager 2 revealed two dark, narrow rings, and a couple of broader, dimmer rings. The rings also contain large amounts of dust, produced by collisions between the larger particles. Unlike Uranus, Neptune's rings lie above the upper limit of the planet's atmosphere so the dust stays where it is produced – it is not dragged by friction towards the planet. The rings are so sparse that a passing astronaut would not be able to see the rings with the naked eye. He might just be able to make out the brighter 'arcs' – denser and brighter segments of the rings. The arcs contain extra material that is chipped off a number of small 'moonlets', each about ten kilometres across. However, the way in which the arcs are maintained is a mystery. Collisions between particles ought to make them spread out evenly through the ring, but some unknown force appears to be keeping the material in the arcs.

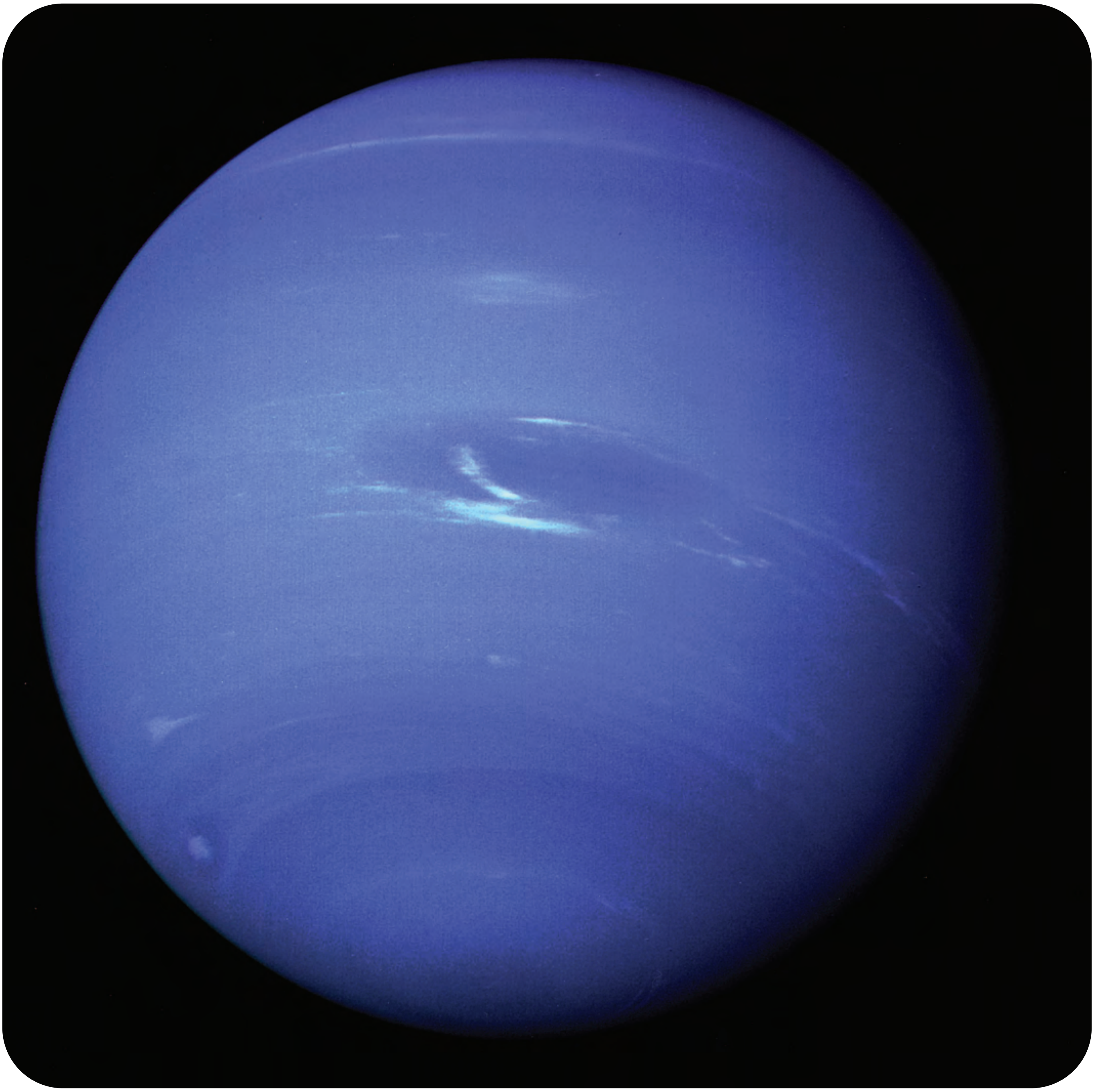
Active geysers on Triton

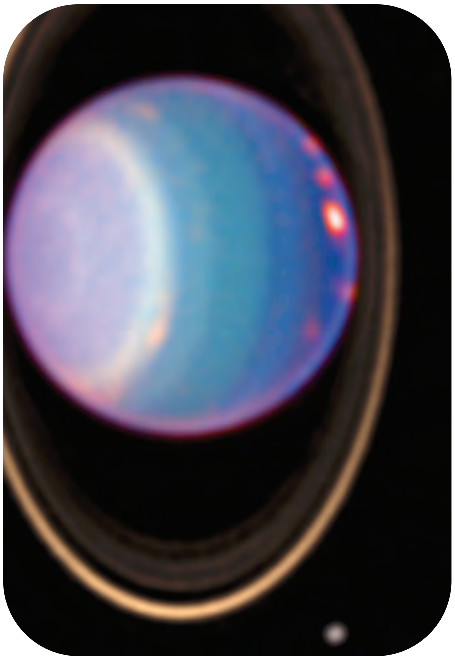
Before the Voyager flyby, two moons of Neptune were known: Triton and Nereid. Triton, the largest, is about two-thirds the size of Earth's Moon. It is made of solid rock and ice and has a tenuous atmosphere of nitrogen and methane. The surface of Triton is the coldest known place in the solar system – just 38 degrees above absolute zero! Pluto may be colder but we have not been able to measure its temperature accurately. Triton has pink polar ice caps where its atmosphere has literally frozen out. On such a frigid world, astronomers were astonished to find active geysers – not spouting water but nitrogen. It is thought that the ice on Triton traps and magnifies the Sun's heat, causing the frozen nitrogen to evaporate. Occasionally, pockets of nitrogen burst through the icy crust, sending plumes thousands of metres above Triton's surface.

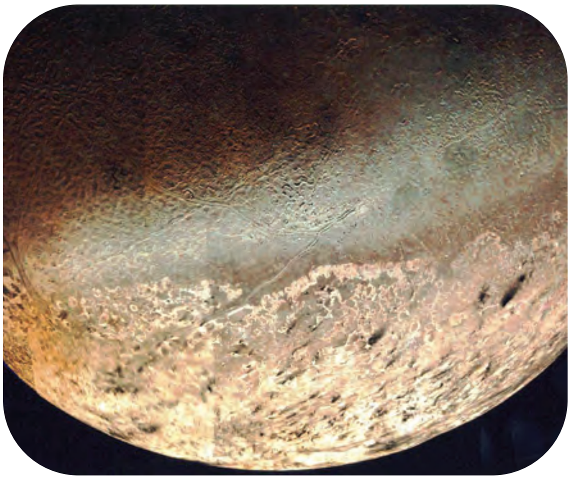
Other features on Triton are equally fascinating. There are virtually no craters; instead, much of the surface is covered with peculiar 'dimples' and long ridges. These ridges may be fractures formed when the icy crust broke apart. There are also round basins about 400 kilometres across that appear to have been flooded by liquids from the interior. The 'lava' flows may consist of water and ammonia. At the edge of the polar ice cap, there are dark plains with bright rims. The origin of these bizarre landscapes is still hotly debated – but most scientists now think that Triton must once have been completely molten.

The moon that goes backwards

Another peculiar fact about Triton is that it orbits its planet in a retrograde fashion. In other words, it goes around Neptune the opposite way that the planet itself is rotating. Looking at Neptune from above its north pole, it turns in an anti-clockwise direction – but Triton moves around the planet in a clockwise direction. According to the nebula theory of the origin of the solar system, Neptune and Triton ought to be moving in the same direction. The only way that evolutionary scientists can resolve this problem is to say that Triton was once an independent body that was captured by Neptune. The dynamics of how this might have taken place are difficult to envisage. Two worlds that closely approach one another usually pass by with some alteration to their trajectories. Neptune would only be able to







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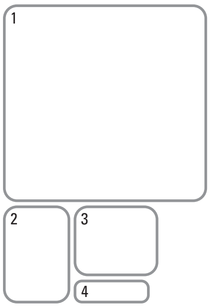

capture Triton if something slowed it down – a cosmic collision with another moon perhaps? Creationists can consider the possibility that Triton was specially created in its current orbit.

The other moon known before the Voyager missions was Nereid – a small moon with a large elliptical orbit. Some have speculated that this strange orbit may be the result of a catastrophic encounter with another body in the past. Voyager 2 did not see Nereid in close-up so we still know little about it. However, Voyager 2 did discover six new moons – all close to Neptune. They are Proteus, Larissa, Galatea, Despina, Thalassa, and Naiad. Three of these moons orbit the planet between its innermost broad ring and the first of the narrow rings. Another lies between the two narrow rings. They are all small, dark, rocky bodies.

Conclusion

Although Uranus and Neptune are regarded as 'twins' they are actually quite different. While the bland appearance of Uranus was something of a disappointment to the Voyager team, the astonishing weather patterns of Neptune more than made up for it. Neptune is a dynamic world, unlike the more passive Uranus. However, the contrasts between these neighbours pose many puzzles for scientists interested in how they formed. Even if a plausible evolutionary scenario could be constructed to explain how Uranus and Neptune originated by natural processes, this would not necessarily indicate that they must have formed that way. The peculiarities of these worlds may indicate instead that Uranus and Neptune were created as unique bodies in the outer solar system – as the Bible's account of creation implies.

TABLE 1.
Data for the five largest moons of Uranus.

Name	Mean distan from Uranus (miles)	Revolution period (days)	Diameter (miles)
Miranda	81,100	1.414	293
Ariel	119,200	2.520	720
Umbriel	166,070	4.144	727
Titania	272,220	8.706	981
Oberon	364,300	13.463	947

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ACKNOWLEDGEMENT

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Although Uranus and Neptune are regarded as 'twins' they are actually quite different

Uranus data file

Average distance from the Sun	19.18 A.U. (28.69 x 10^8 km)
Eccentricity of orbit	0.0461
Maximum distance from the Sun	20.1 A.U. (30.0 x 10^8 km)
Minimum distance from the Sun	18.3 A.U. (27.4 x 10^8 km)
Inclination of orbit to ecliptic	0°46′23″
Average orbital velocity	6.81 km/s
Orbital period	84.013 y (30,685 days)
Period of rotation	17h 14m
Inclination of equator to orbit	97°55′
Equatorial diameter	51,118 km
Mass	8.69 x 10^{25} kg
Average density	1.29 g/cm^3
Gravity	0.919 Earth gravity
Escape velocity	22 km/s
Temperature above cloud tops	-220°C (-364°F)
Albedo	0.35

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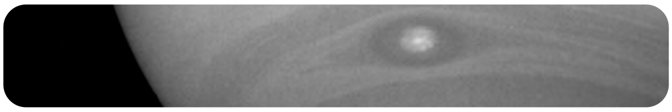
Neptune data file



Average distance from the Sun	30.0611 A.U. (44.971 x 10^8 km)
Eccentricity of orbit	0.0100
Maximum distance from the Sun	30.4 A.U. (45.4 x 10^8 km)
Minimum distance from the Sun	29.8 A.U. (44.52 x 10^8 km)
Inclination of orbit to ecliptic	1°46′27″
Average orbital velocity	5.43 km/s
Orbital period	164.793 y (60,189 days)
Period of rotation	16h 3m
Inclination of equator to orbit	28°48′
Equatorial diameter	49,500 km
Mass	1.030 x 10^{26} kg
Average density	1.66 g/cm^3
Earth gravities	1.19 Earth gravities
Escape velocity	25 km/s
Temperature above cloud tops	-216°C (-357°F)
Albedo	0.35
Oblateness	0.027

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COMETS, THE KUIPER BELT, AND THE OORT CLOUD

DANNY R. FAULKNER

For a long time recent-creationists have used the existence of comets as evidence of recent origin. What is a comet? Comets are small bodies (a comet nucleus is typically a few kilometres across) made of various ices and some dust particles that are mostly microscopic in size. Unlike planets that follow nearly circular orbits around the Sun, comets follow greatly flattened, elliptical orbits. The Sun is located inside and on one side of the ellipse at a point that we call a focus. There is another focus on the other side of the ellipse. The point on the elliptical orbit that is closest to the Sun is the perihelion, while aphelion is the point on the orbit most distant from the Sun. Comets are usually very faint, but when they approach perihelion they brighten tremendously. How do comets indicate young age? Nearly everyone agrees that comets are primordial, that is, they date from the beginning of the solar system. The problem for a long age for the solar system is that at least three mechanisms destroy comets at a rapid rate.

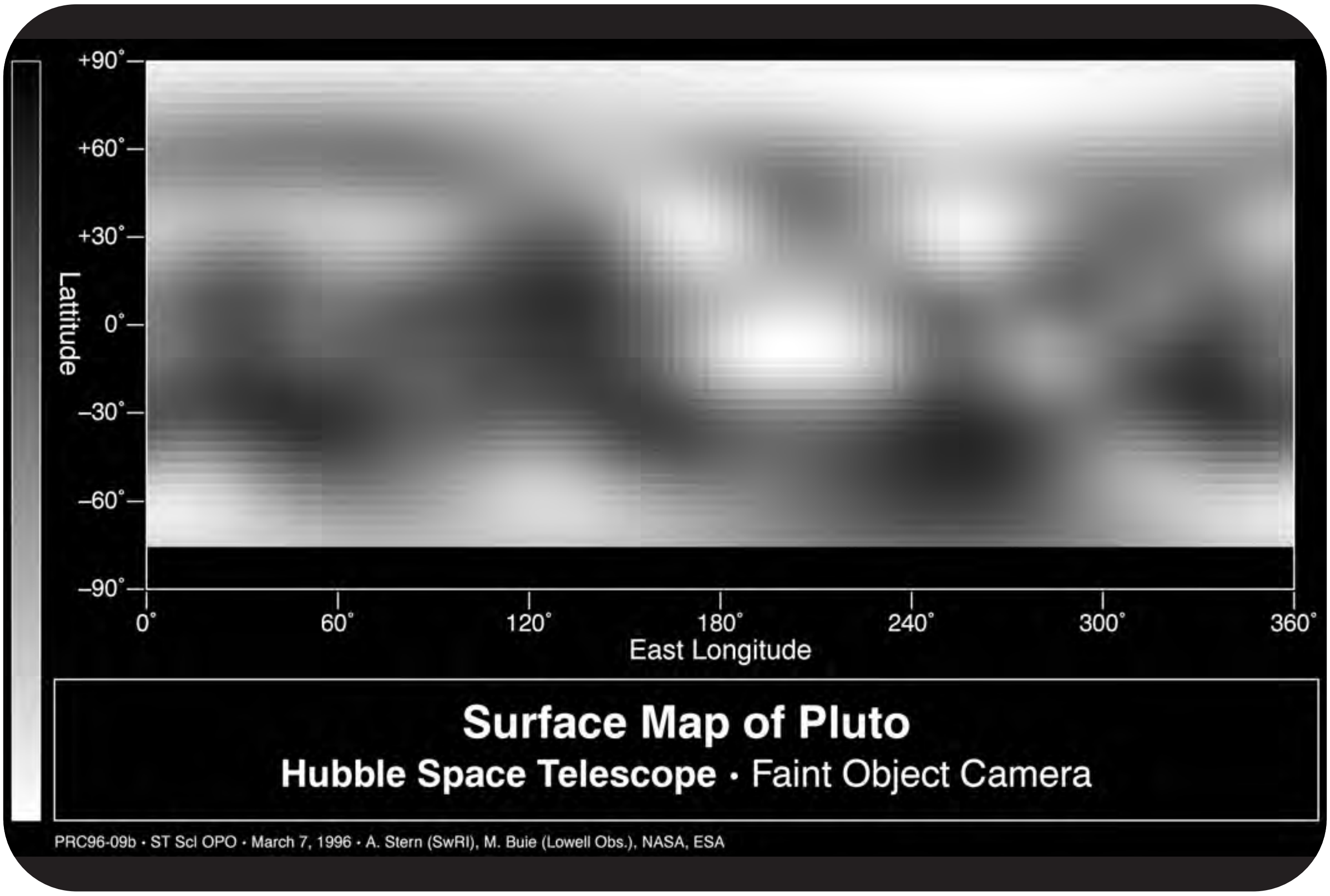
One way that comets are lost is through disintegration. As a comet nucleus nears perihelion once per orbit, the Sun's heat evaporates ice from the nucleus to form a large spherical halo of gas and dust around the nucleus. Astronomers call this halo the coma. A coma may be many thousands of kilometres across. Solar radiation pushes dislodged dust particles outward to form the dust tail, while the solar wind pushes atoms and ions of gas outward to form the ion, or gas, tail. Since significant coma and tail development occurs only near perihelion, comets are very faint except near perihelion. A comet's brightness comes at the expense of its mass. As a comet's mass diminishes, the comet gradually fades. Indeed, astronomers have observed that most periodic comets grow systematically fainter over time. We can estimate how many trips a comet may make before most of its ices evaporate, and likewise we can estimate the maximum orbital period that a comet may have and remain attached to the Sun's gravity. When we multiply these two estimates we obtain a maximum length of time that comets could have been orbiting the Sun. This maximum time is far less than the supposed 4.6 billion year age of the solar system.

A second loss mechanism for comets is gravitational interactions with the major planets, but particularly with Jupiter. A comet often passes near a planet as it journeys through the inner solar system once each orbit. A close passage to a planet causes a gravitational interaction called a perturbation. Half the time a perturbation results in an energy loss and a smaller orbit. For instance, in 1997 Comet Hale-Bopp entered the inner solar system with a period of about 4200 years, but it left the inner solar system with a 2800-year period. The other half of the time a perturbation results in an energy gain and a larger orbit. If the comet originally had a long-period and large orbit, then an energy gain will remove the comet from the Sun's gravitational grasp, and the comet will never return to perihelion. Astronomers have observed this as well. When a comet loses energy, its smaller orbit results in both more frequent trips through the inner solar system and more frequent perihelion passages. Thus, a decreased orbit leads to more rapid loss through both evaporation and more frequent gravitational perturbations.

A third comet loss mechanism is collisions with planets. This was well illustrated by Comet Shoemaker-Levy IX when it collided with Jupiter during the summer of 1994. This small comet had a close interaction with Jupiter two years earlier that altered its orbit and placed it on a collision course with Jupiter. The result of the impact on Jupiter was obvious even with small telescopes, so apparently this was the only comet/planet collision that has happened since the invention of the telescope four centuries ago. While collisions may be rare occurrences, they are catastrophic in that they result in virtually instantaneous destruction of comets. The other two mechanisms continually happen and are thus much easier to observe and assess, but they destroy comets much more gradually. Studies that factor the episodic yet catastrophic nature of comet collisions reveal that the loss rate of comets through collisions is significant compared to the other two loss mechanisms.

Simple calculation shows that all three of these mechanisms so effectively destroy comets that virtually none would remain after 4.6 billion years. This does not automatically mean that the solar system is only thousands of years old, but the existence of comets today is consistent with a very young solar system, but not with a solar system that is billions of years old.

Of course, secular astronomers are well aware of this problem, and so they have developed explanations of how comets can still exist in an ancient solar system. Around 1950 the Dutch astronomer Jan Oort suggested his famous comet cloud as the source of long-period comets. About the same time, the American astronomer Gerard Kuiper suggested that a belt of comets just beyond the outer planets was the source of short-period comets. What are long- and short-period comets? As the names suggest, the length of a comet's orbital period (and hence the size of its orbit) is an important factor. Short-period comets have periods less than 200 years, while long-period comets have periods longer than 200 years. However, there are two other even more important differences between the two groups of comets.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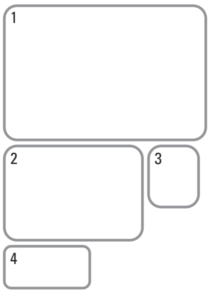
Surface Map of Pluto
Hubble Space Telescope • Faint Object Camera
PRC96-09b • ST ScI OPO • March 7, 1996 • A. Stern (SwRI), M. Buie (Lowell Obs.), NASA, ESA



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Recall that a comet's orbit around the Sun is an ellipse. An ellipse is a plane figure, so an ellipse may define a plane. The Earth's orbit also defines a plane that we call the ecliptic. Different orbits rarely lie in the same plane, so the planes of two different orbits will intersect and form an angle. We call the angle that any other orbit makes with the ecliptic the inclination. The inclinations of short-period comets are usually small, perhaps 20° or less. Of the hundred or so short-period comets, only three defy this rule. On the other hand, long-period comets may have any inclination between 0° and the maximum 90°.

The second difference between the two groups of comets is the direction that the comets orbit the Sun. Short-period comets usually orbit in the same direction as the planets do, that is, they orbit counter-clockwise as viewed from above the Earth's North Pole. About half of the long-period comets orbit counter-clockwise, while the other half orbit the Sun in the clockwise direction.

The fact that the two groups of comets have such very different orbits suggests that the two groups have different sources and/or histories. Kuiper thought that a belt of comet nuclei just beyond the outer planets with orbits close to the ecliptic best explained the existence of short-period comets. Gravitational perturbations of the outer planets would gradually alter the orbits of these comet nuclei. Some of the perturbations would pull comets into the inner solar system where they would become short-period comets. The process of bringing comets into the inner solar system from the Kuiper Belt would preserve the initial counter-clockwise orbital direction and low inclinations of these comets.

The Oort Cloud is a hypothetical spherical cloud of comet nuclei much farther from the Sun than the Kuiper Belt. Oort thought that the gravitational perturbations of passing stars would rob some nuclei of energy and thus alter their orbits so that their perihelia would be close to the Sun. We would see one of these long-period comets each time it passed near its perihelion. The spherical distribution of nuclei in the Oort Cloud causes the orbits of any long-period comets perturbed from the cloud to be random. That is, long-period comets can orbit in either direction and can have any inclination.

Until the 1980s most astronomers thought that perturbations of Jupiter and the other large planets could slowly convert long-period comets into short-period comets. Therefore, astronomers largely ignored the Kuiper Belt in favour of the Oort Cloud as the ultimate source of both kinds of comets. However, computer simulations done about two decades ago showed that this conversion was far too inefficient to account for short-period comets. The rate of destruction was so much more rapid that comets were destroyed long before any significant number of short-period comets could be produced. Thus, the Kuiper Belt has enjoyed resurgence among astronomers the past two decades.

Despite the differences between the orbits of the two types of comets, spectroscopic studies reveal that the two kinds of comets have the same composition. How do astronomers explain this? Astronomers have an evolutionary theory of the origin of the solar system. The Sun supposedly formed from a cloud of gas and dust. Most of the matter in the cloud collapsed to form the Sun, while the remaining matter flattened into a disk around the Sun. Out of this disk, matter supposedly coalesced into small solid bodies that astronomers call planetesimals. The planets later formed from the amalgamation of the planetesimals. The inner solar system near the forming Sun would have been hotter, so the planetesimals there would have boiled off and lost the lighter elements such as hydrogen. Planetesimals farther from the Sun would have been cooler and thus retained their lighter elements. This explains why planets that formed close to the Sun have rocky composition, while planets farther from the Sun have gaseous composition. Small bodies such as satellites and asteroids, that formed in the inner solar system are rocky, while those that formed farther out tend to be icier.

Astronomers now think that comet nuclei are planetesimals that formed just beyond the orbit of Neptune. Being so far from the Sun, these bodies ought to be icy. Given their location and low orbital inclination, these nuclei obviously fit the definition of the Kuiper Belt. Some gravitational perturbations of the outer planets would pull some of these nuclei into the inner solar system to become short-period comets. Other gravitational perturbations would boost other nuclei into random and much larger orbits far from the Sun. That is, some gravitational perturbations would populate the Oort Cloud. Thus, the Kuiper Belt is supposed to be the original source of all comets.

Is there evidence that any of this is true? Any nuclei in the Oort Cloud would be far too small and much too far away for us to see from the Earth. Even the late Carl Sagan noted:

> *"Many scientific papers are written each year about the Oort Cloud, its properties, its origin, its evolution. Yet there is not yet a shred of direct observational evidence for its existence." (Sagan and Druyan, 1997, p.210).*

If something is not observable, can we say that it is scientific?

On the other hand, astronomers claim evidence of the Kuiper Belt. About a dozen years ago, a team of astronomers began searching for small bodies beyond the orbit of Neptune. To date this team has discovered several hundred such objects. If these bodies were located elsewhere in the solar system we would call them asteroids. The largest of these asteroids is about half the size of the planet Pluto. Many of these objects have orbits very similar to Pluto. Given the flattened orbit of Pluto, its high orbital inclination (17°), and Pluto's low density suggesting that it is made of ice, many astronomers now think that Pluto may be the largest comet nucleus. However, are all of these small bodies actually comet nuclei? The smallest of these asteroids is more than ten times larger than the largest comet nucleus ever observed. The disparity in volume is even greater, because a tenfold increase in diameter corresponds to a thousand-fold increase in volume. The volume of a comet nucleus is the true measure of its potential to brighten at perihelion. Is it realistic or even plausible that these monstrous bodies are indeed comet nuclei? If so, why have we never seen a comet so large?

Evolutionary scientists continue to fashion ideas to explain the great age of the world. There is no evidence that the Oort Cloud exists, so the Oort Cloud is hardly a scientific concept. There is reasonable doubt about the evidence for the Kuiper Belt. Twenty-five years ago, few astronomers thought that the Kuiper Belt existed. Instead, they were confident that the unobservable Oort Cloud could explain all comets. Today most astronomers are sure that the Kuiper Belt can ultimately explain all comets. Given the ever-changing nature of science, the only thing that we can be sure of is that in a few years this picture will completely change again. As Christians, we can be sure that God created the world in the recent past, as He said in His Word. The existence of comets today bears witness to this fact.[1]

NOTE

[1] *For more information about comets and the age of the solar system, please see this article: http://www.answersingenesis.org/docs/4108.asp (downloaded 26 June 2004).*

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Pluto data file

Average distance from the Sun	39.44 A.U. (59.00 x 10^8 km)
Eccentricity of orbit	0.2484
Maximum distance from the Sun	19.24 A.U. (73.66 x 10^8 km)
Minimum distance from the Sun	29.64 A.U. (44.34 x 10^8 km)
Inclination of orbit to ecliptic	17°9′3″
Average orbital velocity	4.73 km/s
Orbital period	247.7 y (90,465 days)
Period of rotation	6d 9h 21m
Inclination of equator to orbit	122°
Equatorial diameter	2,370 km
Mass	1.2 x 10^{22} kg
Average density	2.0 g/cm^3
Surface Gravity	0.06 Earth gravity
Escape velocity	1.2 km/s
Temperature above cloud tops	-230°C (-382°F)
Albedo	0.5

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THE FOUNDATIONS OF OUR FAITH

J. H. JOHN PEET

3. THE DOCTRINE OF NATURE

THE BIBLICAL DOCTRINE OF NATURE BEGINS WITH GENESIS 1:1, "IN THE BEGINNING, GOD CREATED THE HEAVENS AND THE EARTH." NATURE WAS CREATED BY GOD AND IS, THEREFORE, SUBJECT TO HIM. IT IS NOT TO BE WORSHIPPED BUT IS TO POINT US TO GOD (ROMANS 1:20). ITS PLACE IS ASSURED BY BEING THE WORK OF GOD'S HANDS. BEING CREATED BY GOD, THE SUN ITSELF CANNOT BE GOD AND CANNOT BE AN OBJECT OF WORSHIP. IN FACT, WHEN COMPARED TO THE ANCIENT RELIGIONS OF EGYPT, MESOPOTAMIA, ETC., THE BIBLICAL TEACHING ON CREATION IS A COMPLETE, ABSOLUTE CONTRAST.

Let us consider firstly that **it witnesses to God**. One of the most significant comments made by Richard Dawkins was in an interview recorded in *The Daily Telegraph*. The interviewer asked him about his fascination with the tropical rainforest and he replied, "I've contemplated a tropical rainforest and felt a tremendous sense of awe and worship." The interviewer notes that there was a pause and then Professor Dawkins added, "Not, of course, that there is anything to worship." This shows that even though he may reject the obvious implication of his comments, there is a deep seated conviction that causes him to make such a confession. Scripture says that we are without excuse for denying the Creator. How often do we hear the word 'design' in nature programmes on the radio or television? The purpose of nature is not to point us back to a single cell, but to God.

Just as a piece of art betrays something of the character of the artist, so nature speaks of the attributes of our Creator. For the psalmist, for example, the earth speaks of God's goodness (Psalm 147:9), His eternity (Psalm 90:1-2), His immutability (Psalm 102:25-27), His transcendency (Psalm 97:9) and His keeping power (Psalm 121:2). The heavens (the topic of this issue of *Origins*) declare God's glory (Psalm 19:1), His power (Psalm 33:6), His faithfulness (Psalm 36:5), His righteousness (Psalm 97:6), His mercy (Psalm 103:11) and His wisdom (Psalm 136:5). David sums it up as the whole creation praising its Maker (Psalm 148). In a similar way, Jeremiah (31:35-37) speaks for God showing that the world around demonstrates God's unfailing faithfulness to His people. As you read through this issue of *Origins*, may that be your experience.

We are also told in Scripture of the **purpose of nature**. It is created for man's benefit (Genesis 1:29-30; 1:14-15; 2:9; etc.). On the one hand, it provides us with food, clothing, medicines, materials for construction and for making fire. It also provides us with the means for measuring time and for finding our direction through the world. Some years ago I was in the Middle East and needed to travel from one place to another by sea. A local villager provided the transport (a fishing boat), but he had no time-piece. We agreed a time for departure and for him to return and pick us up. Using only the Sun's position, he arrived right on time! Many animals find their direction using the Sun (especially ultraviolet radiation) and the Earth's magnetic field – exactly as sailors used to do before modern radar and satellite communication systems. But God also provided this world for our enjoyment (1 Timothy 4:4).

The Bible also teaches that the cosmos was created for God's pleasure (Revelation 4:11). God delights in what He has made. It is the natural outworking of His own nature. Why did God create so many animals with the potential for speciation (even beyond the needs for environmental adjustment)? Why are there so many stars? Surely because He delights in diversity! Think how uninteresting the sky would be if we had only the Moon! Because God is beautiful, He makes things beautiful so that we may enjoy them too. The complexity of the heavens aids our worship by helping us to realise how great God is (Psalm 8:1-2). They also make us realise how special, how unique, this planet is and so how special we must be to God (Psalm 8:4). I believe the variety of the planets, for example, can also be seen to demonstrate God's care for us. The largeness of Jupiter means that it attracts things like asteroids and comets to itself: that protects planet Earth from them.

All this has another important implication: **our environmental responsibility**. God created us to care for His creation – not exploit it greedily (Genesis 1:28). We are stewards, managers and not owners. The Earth is to be subdued to produce food, etc. The thrust of Genesis 2:15 is preservation. We are accountable for our use or abuse of this world (and, indeed, the cosmos). It does matter!

God cares about His creation (Matthew 6:26-30) and will hold us to account. The Levitical laws include care for the animals and the environment. "The righteous man cares for the needs of his animals" (Proverbs 12:10); righteousness is practical! We are to give the animals a sabbath rest as well as mankind! The creationist protects the environment because it has wonder, awe and real value. The value of a tree is not through worshipping it, but by recognising why God has made it and treating it accordingly.

Look around at the work of God. Look at Scripture's injunctions concerning our use of it. Now, rejoice and thank God for His generosity and the beauty of His work.

BOOK REVIEWS: ASTRONOMY SPECIAL

Stars and Their Purpose: Signposts in Space

by Werner Gitt. Christliche Literatur-Verbreitung, Bielefeld.
Second Edition. 2000. 217pp.
ISBN 3-89397-787-2.

This little book offers the reader many fascinating facts about the stars and galaxies observed by astronomers. Why did God make the stars? Is the Universe the result of chance or purpose? What was the Star of Bethlehem? Is it possible to know the Creator personally? The author, a Professor at the German Federal Institute of Physics, points us to the answers that may be found in the Bible. Appendices deal with the solar system, the Big Bang, and explanations of astronomical concepts that may be unfamiliar.

The Earth, the Stars, and the Bible

by Paul M. Steidl. Presbyterian and Reformed, Phillipsburg, New Jersey. 1979. 250pp.

In 1980, BCS Vice-President David Watts described this as "an invaluable guidebook" and "the leading creationist volume with overall coverage of the scientific aspects of astronomy" (Watts, 1980). Although it is now out-of-print and in need of revision, it is still worth reading if you can find a second-hand copy or borrow it from a library. The author discusses many branches of astronomy from solar system exploration to the classification of stars and galaxies. He usefully critiques naturalistic theories of the origin and development of our Universe. He shows that biblical creation provides a satisfying alternative framework for astronomy, but also highlights where more research is needed. This is a commendably thorough treatment of the subject – but remember to supplement your reading of it with more recent works!

He Made the Stars Also: What the Bible Says About the Stars

by Stuart Burgess. Day One Publications, Epsom. 2001. 186pp. ISBN 1-903087-26-0.

The author of this book is a Reader in Engineering Design at Bristol University. In this book, he brings his engineer's eye to bear upon the Universe in which we live. He describes a multitude of ways in which the Earth and the stars are designed for the benefit of man and to glorify their Creator. One of the chapters focuses on the beauty of the Universe and another on the attributes of God revealed in the stars. The second half of the book deals with the question of extraterrestrial life, and points us to the Lord in whom salvation may be found. Readers will find this an exciting book that will encourage their faith.

Voyage to the Planets

by Richard B. Bliss and Donald B. DeYoung. Institute for Creation Research, El Cajon, California. 1994. 128 pp. ISBN 0-932766-32-3.

A fictional journey into space by two young students, Ann and Jonathan, provides an opportunity for readers to accompany them on a voyage of discovery. Led by Captain Venture, the youngsters travel to the planets and moons of our solar system looking for evidence of God's handiwork. The failures of evolutionary thinking are brought to the reader's attention and creation-based alternatives are suggested. Scientific concepts are simply explained and there is a helpful glossary of terms. Questions are posed at the end of each chapter to review the material and stimulate further study. This book would be appropriate for teenage readers.

God and Cosmos: A Christian View of Time, Space, and the Universe

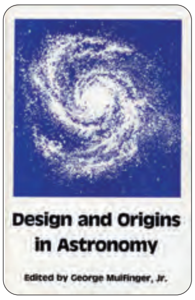
by John Byl. The Banner of Truth Trust, Edinburgh. 2001. 243pp.
ISBN 0-85151-800-1.

Bill Worraker (2003) reviewed this book in more detail in *Origins* 35. However, it warrants another mention here. Although the author is highly sceptical of the apologetic value of biblical cosmologies, there is much to provoke thought in this book. Byl traces the historical development of cosmological ideas, focusing on the problems of the Big Bang theory. He highlights the philosophical presuppositions involved in the construction, assessment, and selection of cosmological models. The Big Bang theory is shown to contradict not only the Bible's account of beginnings, but also its teaching about the future.

Design and Origins in Astronomy

Edited by George Mulfinger. Creation Research Society Monograph Series Number 2, CRS Books. 1983. 152pp. ISBN 0-940384-03-5.

This is a collection of pioneering articles in creation astronomy from the pages of the *Creation Research Society Quarterly*. Readers looking for more technical material will find much to enjoy here. Topics addressed include teleology and design, the origin of the Universe, the redshift controversy, and solar system discoveries. Theologian John Whitcomb provides a Scriptural framework for astronomy. One caution is necessary – this volume was published in 1983 and some of the content would need revision today (e.g. the chapters on the shrinking sun and solar neutrinos). This is partly remedied by the companion volume reviewed over the page.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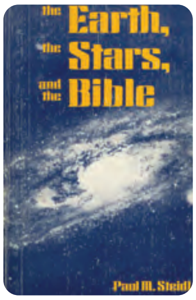

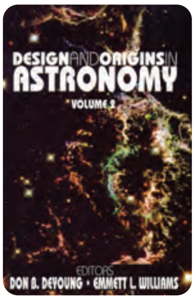
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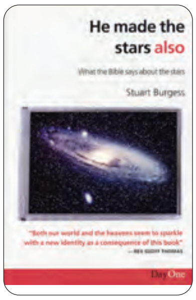

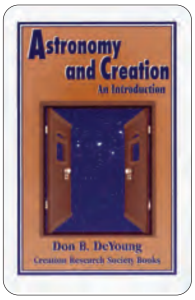

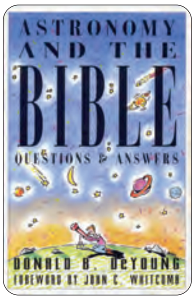

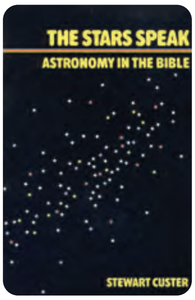

BCS does not operate a book order service, but we advise people with book requirements to direct their enquiries to Dr Marc Surtees, Paradigm Shift, 267B Leith Walk, Edinburgh EH6 8PD. Telephone: 0131 - 5546363. Email: msurtees@paradigmshift.org.uk. Web site: http://www.paradigmshift.org.uk.

Design and Origins in Astronomy Volume 2

Edited by Don B. DeYoung and Emmett L. Williams. Creation Research Society Monograph Series Number 12, CRS Books. 2002. 163pp. ISBN 0-940384-26-4.

This second volume also consists of papers selected from the *Creation Research Society Quarterly*. The first chapter provides short biographical sketches of godly astronomers, while the other chapters deal with scientific topics. There is material here on lunar and terrestrial craters, the Sun and the Moon, planetary magnetic fields, comets, dark matter, and the speed of light controversy. In 'Towards a creationist astronomy', Danny Faulkner and Don DeYoung provide some useful suggestions for future research topics.

Astronomy and Creation: An Introduction

by Don B. DeYoung. Creation Research Society Reader Series Number 1. CRS Books. 1995. 59pp. ISBN 0-940384-17-5.

This concise little book considers five key questions: (1) Did the Universe begin supernaturally or spontaneously? (2) Did order arise from design or chance? (3) Do we live in a universe or multiverse? (4) Is the Universe time scale short or long? (5) Does the Universe display degeneration or evolution? Short essays at the end look at God and the Big Bang, the concept of mature creation, and some ideas for activities that would encourage further study. There is also a short bibliography, glossary, and index.

The Astronomy Book

by Jonathan F. Henry. Master Books, Green Forest, Arizona. 1999. 80pp. ISBN 0-89051-250-7.

This is one of the 'Wonders of Creation' series from Master Books. It is a large format publication and richly illustrated with colour paintings, charts, and photographs to aid understanding. It covers the size and origin of the Universe, including evidence against the Big Bang and possible solutions to the problem of the travel-time of distant starlight. The author favours an explanation involving a higher speed of light in the past. Evidence for the design and young age of astronomical bodies is presented. There are also fascinating insights concerning catastrophes in the universe, such as the death of stars, the destruction of moons and planets, meteor impacts, and global flooding on Mars. This book is written for Christian home-school pupils, but would be suitable reading for anyone aged 9 years up. It makes learning about the Universe fun! Highly recommended for all Christian families.

The Stars Speak: Astronomy in the Bible

by Stewart Custer. Bob Jones University Press, Greenville, South Carolina. 1977. 195pp. ISBN 0-89084-059-8.

This unusual book is a guide to the astronomy of the Bible. It takes the reader on a tour of the night sky through the seasons. The stars of spring, summer, autumn, and winter are described – and we learn of biblical references to the star patterns and constellations. There are also chapters on the Star of Bethlehem, our Sun and Moon, the planets and comets of our solar system, and the galaxies. The errors of astrology are also noted. This easy-to-understand book will add to the reader's appreciation of the heavens that God has made.

Starlight and Time: Solving the Puzzle of Distant Starlight in a Young Universe

by D. Russell Humphreys. Master Books, Colorado Springs, Colorado. 1994. 133pp. ISBN 0-89051-202-7.

The Bible says that the universe is only thousands of years old, and yet we can see stars that are billions of light-years away. A number of solutions have been proposed to explain this paradox, and this book outlines one of them. Humphreys' theory is based on the fact that, according to Einstein's general theory of relativity, gravity distorts time. He argues that if a bounded Universe (i.e. one with an edge and a centre) had expanded from a much smaller size during Creation Week, then time dilation effects would have meant that clocks at the edge ran at different rates to clocks at the centre. If it was near the centre, six days could pass on Earth while the equivalent of 'billions of years' would pass further out. This proposal has proved controversial, even among other young-universe creationists. Read this book and see what you think!

The Bible and Astronomy

by John C. Whitcomb. BMH Books, Winona Lake, Indiana. 1984. 32pp. ISBN 0-88469-156-X.

Written for those who are discouraged by secular theories about the origin, nature, and destiny of the universe, this introductory booklet provides some useful material. The author, a well-respected professor at Grace Theological Seminary, outlines what the Bible says about the heavens and their purpose. The booklet concludes by presenting the reader with the Creator who alone can meet our needs.

Astronomy and the Bible: Questions and Answers

by Donald B. DeYoung. Baker Book House, Grand Rapids, Michigan. Second Edition. 2000. ISBN 0-8010-2991-0.

Has the origin of the solar system been determined? What do we know about the stars named in Scripture? Was there a Big Bang? Can astronomy lead a person to God? One hundred such questions are answered concisely and simply from a Christian perspective in this book. The material is organized into sections for easy reference and a glossary of terms is provided. This is an excellent 'appetite-whetter' on creation-based astronomy for the ordinary Christian.

The Moon: Its Creation, Form and Significance

by John C. Whitcomb and Donald B. DeYoung. Baker Book House, Grand Rapids, Michigan. 1978. 180pp. ISBN 0-8010-9619-7.

This classic volume has been described by BCS Vice-President Professor David Watts (1979) as "a magnificent exposition of the subject". It is certainly an engaging overview of what we know about the Moon from a Christian perspective. We learn about the programme of lunar exploration, the geology of the Moon, and transient lunar phenomena – mysterious flashes and glows that suggest that our nearest neighbour in space may not be the cold, dead world we often imagine. The distinctive features of the Moon are discussed from a design point of view and naturalistic ideas of how the Moon formed are found wanting. There are appendices on the dependability and destiny of the Moon, and the spiritual disaster of Moon worship. Amply illustrated with photographs, diagrams, charts and tables, this is a welcome introduction to an absorbing subject.

Our Created Moon

by Don B. DeYoung and John C. Whitcomb. Master Books. 2003. 160pp. ISBN: 0-8905-1403-8.

This is a simplified and updated version of the authors' 1978 book on the Moon. Using a question-and-answer style, they explain the characteristics of the Moon and the purposes for which it was made. They also critique the various evolutionary theories of its origin. The last section provides answers to critics.

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Watts, D.C. (1980). Book review. Biblical Creation, *2(7):96-97.*

Worraker, B. (2003). Book review. Origins, *(35):17.*

RECOMMENDED WEB SITES ON OUR SOLAR SYSTEM

COMPILED BY WAYNE SPENCER

http://www.psrd.hawaii.edu/	Planetary Science Research Discoveries
http://spacescience.nasa.gov/	NASA space science site
http://www.planetary.org/	The Planetary Society
http://www.msss.com/	Malin Space Science Systems (Mars)
http://www.nytimes.com/library/national/science/solar-index.html	Nice overview of the solar system
http://www.lpi.usra.edu/	The Lunar & Planetary Institute
http://www.esa.int/export/esaSC/index.html	The European Space Agency
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http://galileo.jpl.nasa.gov/	The Galileo mission
http://saturn.jpl.nasa.gov/index.cfm	The Cassini/Huygens mission
http://mpfwww.jpl.nasa.gov/mgs/index.html	Mars Global Surveyor mission
http://www.solarviews.com/eng/tercrate.htm	Earth impact sites

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IMAGE CAPTIONS

06 OUR SOLAR SYSTEM AND ITS ORIGIN

1. **A global map of Mars** (Mollweide projection), showing the regions imaged by the Hubble telescope during the planet's closest approach to Earth. Latitudes below about 60 degrees south were not viewed by the telescope because the planet's north pole was tilted towards Earth during this time. © NASA.
2. **Giotto spacecraft**. © NASA.
3. **An active volcanic eruption on Jupiter's moon Io** is captured in this image taken by the Galileo spacecraft on 22 February 2000. White and orange areas on the left side of the picture show newly erupted hot lava, seen in this false colour image because of infrared emission. © NASA.
4. **Mars Viking lander**. © NASA.
5. **Mariner 9 spacecraft**. © NASA.
6. **The Mars Pathfinder rover, Sojourner**. © NASA.

14 THE SUN – THE GREATER LIGHT TO GOVERN THE DAY

1. **Schematic of the recognised zones of the Sun** [from the University of Columbia website at http://www.seas.columbia.edu/~ah297/un-esa/sun/sun-chapter1.html].
2. **Schematic of heat transfer mechanisms in the radiative and convective zones** [from the University of Columbia website].
3. **A total solar eclipse** showing details of the corona (white) and prominences (red) [from the NASA solar physics website http://science.nasa.gov/ssl/pad/solar/default.htm].
4. **Sunspots** [from the NASA solar physics website].
5. **Detail of sunspots and granulations** [from the NASA solar physics website].
6. **A magnetic loop** delineated by gas above an active region, photographed in ultraviolet light [A NASA/JPL photograph published by Armagh Planetarium].
7. **A huge solar explosion** which hurled 6 billion metric tons of gas into space [A NASA/JPL photograph published by Armagh Planetarium].

16 MERCURY – THE PLANET OF MYSTERY

1. After passing on the darkside of the planet, Mariner 10 photographed the other, somewhat more illuminated hemisphere of **Mercury**. The north pole is at the top, two-thirds down from which is the equator. © NASA/JPL.
2. **A computer photomosaic of the Caloris Basin** – the largest basin on Mercury. © NASA/JPL.
3. **Intercrater plains and heavily cratered terrain** on Mercury photographed by Mariner 10. © NASA.

22 THE GOLDILOCKS PLANET

1. **The Earth as seen by the Apollo 17 astronauts** as they left Earth orbit en route to the Moon. Taken on 7 December 1972, it was the first time that the trajectory of an Apollo mission enabled a view of the south pole. © NASA.
2. **A drawing by Percival Lowell** showing 'canals' on the surface of Mars.
3. **The cloud tops of Venus** in an ultraviolet-light image taken by the Hubble Space Telescope on 24 January 1995. Venus is covered with clouds made of sulphuric acid, rather than the water-vapour clouds found on Earth. © NASA/JPL.
4. **The largest known volcano in the solar system, Olympus Mons**. This image is a photomosaic taken by Viking 1 on 22 June 1978. The central edifice of Olympus Mons has a summit caldera 24 km above the surrounding plains. Surrounding the volcano is an outward-facing scarp 550 km in diameter and several kilometres high. Beyond the scarp is a moat filled with lava, most likely derived from Olympus Mons. Farther out is an aureole of characteristically grooved terrain, just visible at the top of the frame. © NASA.
5. **A global view of the surface of Venus** assembled from Magellan radar mosaics and Pioneer Venus Orbiter data. The simulated hues are based on colour images recorded by the Soviet Venera 13 and 14 spacecraft. © NASA/JPL.
6. **This view of Mars** in approximately true colour reveals details in an impact crater informally named "Fram" in the Meridian Planum region. The picture is a mosaic of frames taken by the panoramic camera on NASA's Mars Exploration Rover Opportunity during the rover's 88th martian day on Mars, on 23 April 2004. The crater spans about 8 metres (26 feet) in diameter. © NASA/JPL.

27 MAN ON THE MOON – A MYSTERY REVEALED

1. **A colour image of the Moon** taken by the Galileo spacecraft on 9 December 1990, at a range of about 350,000 miles. © NASA.
2. **Buzz Aldrin walking on the Moon** on 20 July 1969. This photograph was taken by fellow astronaut Neil Armstrong with a 70 mm lunar surface camera. © NASA.
3. **A gold replica of the olive branch**, traditional symbol of peace, left on the Moon's surface by Apollo 11 crew-members. The gesture represented a wish for peace for all mankind. © NASA.

30 THE RINGED GIANTS – JUPITER AND SATURN

1. **Voyager 2 returned this view of Saturn and its ring system** when the spacecraft was 13.9 million kilometres (8.6 million miles) away and approaching the large, gaseous planet at about l million km (620,000 miles) a day. © NASA/JPL.
2. **Saturn's shadow falls upon its ring system** in this look-back from Voyager 1 taken on 16 November 1980, four days after the spacecraft flew past the planet. © NASA/JPL.
3. **Saturn and its magnificent ring system** imaged by the Wide Field Planetary Camera 2 onboard the Hubble Space Telescope. © NASA/STScI/AURA.

34 THE RINGED GIANTS – JUPITER AND SATURN

1. **The Minos Linea region on Europa**. This false-colour, composite image was taken on 28 June 1996 by the Galileo spacecraft. The bands and lineations indicate the presence of contaminants in the ice. © NASA/JPL.
2. **Io, the most volcanic body in the solar system**, is seen in front of Jupiter's cloudy atmosphere in this image from the Galileo spacecraft, taken on 7 September 1996. © NASA/JPL.
3. **An image of Jupiter's satellite, Callisto**, taken by Voyager 2 from a distance of 2,318,000 kilometres (1,438,000 miles). © NASA/JPL.
4. **Jupiter's Great Red Spot**, as imaged by the Hubble Space Telescope. © NASA/JPL.
5. **Europa, the smallest Galilean satellite**, in an image taken on 4 March 1979, from a distance of about 2 million kilometres (1.2 million miles), by Voyager 1. © NASA/JPL.
6. **Jupiter and its four planet-size moons**, called the Galilean satellites, were photographed by Voyager 1 and assembled into this collage. They are not to scale but are in their relative positions. Reddish Io (upper left) is nearest Jupiter; then Europa (centre); Ganymede and Callisto (lower right). © NASA.
7. **Ganymede, Jupiter's largest satellite**, imaged on 4 March 1979 by Voyager 1 from a distance of 2.6 million kilometres (1.6 million miles). © NASA/JPL.

38 THE OUTER LIMITS – URANUS AND NEPTUNE

1. **Neptune photographed by Voyager 2** from a range of 4.4 million miles from the planet, 4 days and 20 hours before closest approach. The picture shows the Great Dark Spot and its companion bright smudge; on the west limb the fast moving bright feature called Scooter and the little dark spot are visible. © NASA/JPL.
2. **The ring system of Uranus** photographed in 1998 by Hubble's Near Infrared Camera and Multi-Object Spectrometer. © NASA/STScI.
3. **Triton, Neptune's largest satellite**, imaged by Voyager 2 during its close flyby on 25 August 1989. The large south polar cap at the bottom of the image is highly reflective and slightly pink in colour; it may consist of a slowly evaporating layer of nitrogen ice deposited during the previous winter. © NASA/JPL.
4. **A 'family portrait' of Uranus' five largest moons** compiled from images sent back in 1986 by Voyager 2. From left, in order of increasing distance from the planet, they are Miranda, Ariel, Umbriel, Titania and Oberon. © NASA/JPL.

42 COMETS, THE KUIPER BELT, AND THE OORT CLOUD

1. **The first image-based surface map of the solar system's most remote planet, Pluto**. The map, which covers 85% of the planet's surface, confirms that Pluto has a dark equatorial belt and bright polar caps. © NASA/ESA.
2. **Comet P/Halley taken on 8 March 1986** by W. Liller, Easter Island, part of the International Halley Watch (IHW) Large Scale Phenomena Network. © NASA.
3. **The nucleus of Comet P/Halley** taken with the Halley Multicolour Camera on the European Space Agency's Giotto spacecraft. © NASA.
4. **The clearest view yet of the distant planet Pluto and its moon, Charon**, as revealed by the Hubble Space Telescope. The image was taken by the European Space Agency's Faint Object Camera on 21 February 1994 when the planet was 2.6 billion miles (4.4 billion kilometres) from Earth; or nearly 30 times the separation between Earth and the Sun. © ESA/ESO/NASA.

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SPECIAL ISSUE: The Solar System